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A Continuous Helical Welded Seam For Helically Corrugated Steel Pipe

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Nordlin, E.F.; Jonas, P.G.; and Scharosch, D.L.

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16. ABSTRACT
Seam performance of helically corrugated galvanized steel pipe utilizing the continuous helical welded seam process is discussed. The California Division of Highways accepts corrugated steel pipe with seams consisting of (1) rivets, (2) spot welds, and (3) continuous helical lock seam. A continuous helical welded seam is added to this group as the result of the findings of this research project. Destructive tests performed on numerous specimens of seam removed form production line samples of corrugated metal pipe of various diameters and metal thicknesses demonstrated the manufacturing ability to produce continuous wleded seams satisfactory for this use. A "cup test" has been substantiated as an effective nondestructive quality control test for indicating the acceptability of the continuous welded seam in lengths of corrugated steel pipe. This test method was developed as part of the research project.

17. KEYWORDS
corrugated steel pipe, welding, non-destructive testing, test methods, physical testing, strength, seam welds

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HIGHWAY RESEARCH REPORT

A CONTINUOUS HELICAL WELDED SEAM FOR HELICALLY CORRUGATED STEEL PIPE

69-46

STATE OF CALIFORNIA
BUSINESS AND TRANSPORTATION AGENCY
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT
RESEARCH REPORT
NO. M & R 646427

State of California

Transportation Agency

Memorandum

To : Mr. George A. Hill
Assistant State Highway Engineer
Engineering Services

Date: May 8, 1969

File : M & R 646427

From : Department of Public Works—Division of Highways
Materials and Research Department

Subject :

Submitted for your consideration and approval is a final research report entitled, "A Continuous Helical Welded Seam for Helically Corrugated Steel Pipe".

From this study it was concluded that the continuous helical welded seam, under proper manufacturing quality control, is an acceptable seaming method for helically corrugated galvanized steel culvert pipe. A "cup test" was also developed as an effective nondestructive quality control test for indicating the acceptability of this welded seam.

As a result of this study, the California Division of Highways' Standard Specifications now qualify continuous welded seam corrugated metal pipe as an alternate to riveted, spot welded or lockseam corrugated metal culvert pipe. Test Method No. Calif. T665-B titled, "Seam Quality Control Standard for Helical Continuous Welded Seam Corrugated Metal Pipe" has been established and is a part of this specification.

J Beaton

JOHN L. BEATON
Materials and Research Engineer

EFN:mw
cc: RVPotter
(GAvery)

Attach.

APPROVED

May 12, 1969

George A Hill

Assistant State Highway Engineer

FORM H-AD 38 (REV. 8-66)

STATE OF CALIFORNIA—TRANSPORTATION AGENCY RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

April 1969
Final Report
M & R No. 646427

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

A CONTINUOUS HELICAL WELDED SEAM

FOR HELICALLY CORRUGATED STEEL PIPE

ERIC F. NORDLIN
Principal Investigator

PAUL G. JONAS
Co-Principal Investigator

Dennis L. Scharosch
Co-Investigator

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mr. L. S. Hannibal, Senior Mechanical Engineer, and Mr. T. W. Mackay, Machinist of the Machine Shop, for their constructive ideas in designing and fabricating the necessary jigs and fixtures which expedited the preparation of the specimens used in evaluating the continuous helical welded seam for helically corrugated galvanized steel pipe. The authors also wish to express their appreciation to Armco Drainage and Metal Products for their cooperation in supplying machine welded samples from their Davis, California, plant for physical testing and evaluation.

This is the final report to be issued under a research project titled, "Continuous Welding of Helically Corrugated Metal Pipe". This work was done under the 1967-68 Work Program Authorization 646427. All work was conducted at the California Division of Highways, Materials and Research Department, 5900 Folsom Boulevard, Sacramento, California.

ABSTRACT

REFERENCE: Nordlin, E. F., Jonas, P. G., and Scharosch, D. L. "A Continuous Helical Welded Seam for Helically Corrugated Steel Pipe", Department of Public Works, Division of Highways, Materials and Research Department. Research Report No. 646427, April 1969.

ABSTRACT: Seam performance of helically corrugated galvanized steel pipe utilizing the continuous helical welded seam process is discussed. The California Division of Highways accepts corrugated steel pipe with seams consisting of (1) rivets, (2) spot welds, and (3) continuous helical lock seam. A continuous helical welded seam is added to this group as the result of the findings of this research project. Destructive tests performed on numerous specimens of seam removed from production line samples of corrugated metal pipe of various diameters and metal thicknesses demonstrated the manufacturing ability to produce continuous welded seams satisfactory for this use. A "cup test" has been substantiated as an effective nondestructive quality control test for indicating the acceptability of the continuous welded seam in lengths of corrugated steel pipe. This test method was developed as part of the research project.

KEY WORDS: Corrugated steel pipe, welding, non-destructive testing, test methods, physical testing, strength, seam welds.

TABLE OF CONTENTS

I. INTRODUCTION

The purpose of this research project was to:

1. Determine the acceptability of a continuous helical welded seam for helically corrugated galvanized steel culvert pipe.

2. Determine whether an acceptable quality control test procedure and adequate specifications could be developed for a continuous helical welded seam for helically corrugated galvanized steel culvert pipe.

II. CONCLUSIONS

1. The continuous helical welded seam, under proper manufacturing quality control, is an acceptable seaming method for helically corrugated galvanized steel culvert pipe.

2. A "cup test" described in this report has been substantiated as an effective nondestructive quality control test for indicating the acceptability of the welded seam in lengths of helically corrugated galvanized steel culvert pipe.

III. RECOMMENDATIONS

It is recommended that:

1. The continuous helical welded seam be qualified as an alternate method of fabricating helically corrugated galvanized steel pipe, subject to satisfactory compliance with Test Method No. Calif. T665-B titled, "Seam Quality Control Standard for Helical Continuous Welded Seam Corrugated Metal Pipe" (see Appendix B). This test method was developed on the findings of this research project. As the result of this study, the Standard Specifications of the California Division of Highways now qualify continuous helical welded seam corrugated culvert pipe on this basis.

2. Accumulation of test data will be continued until a time when all possible machine capabilities, size and gage combinations have been physically tested, documented, and correlated with the proposed nondestructive tests.

IV. INFORMATION

The California Division of Highways accepts corrugated metal pipe fabricated by (1) riveting, (2) spot welding, and (3) a continuous lockseam joining practices. A seam fastened by rivets or spot welds has been employed on annularly corrugated metal pipe whereas the lockseam has been used on helically corrugated metal pipe.

A helical continuous welded seam was proposed as an alternate method of fabricating helically corrugated galvanized steel pipe. Hereafter in this report this pipe will be called continuous welded seam pipe.

Riveted corrugated metal pipe construction is acceptable for use on California Division of Highways projects upon satisfactory compliance to AASHO Designation M36. The quality of the spot welded seam is controlled in accordance with Test Method No. Calif. 647. The quality of the continuous lockseam is controlled as specified in Test Method No. Calif. 662. Acceptance by California of continuous welded seam pipe was contingent upon the production line quality of this weld and the development of a test method to assure and control this quality.

The principal manufacturer of continuous welded seam pipe and the supplier of all test samples used during this research project was Armco Drainage and Metal Products, Davis, California.

The machine used to produce the continuous welded seam pipe consists basically of three systems: (1) the continuous corrugating system, (2) the continuous induction welding system, and (3) the automatic pipe cut-off system. When operating, the composite machine generates corrugated metal pipe continuously, utilizing the induction fusion process. Machine stops are required only when a coil end is reached. With a programmed machine pipe cut-off system, the manufacturer has the capabilities of producing pipe in any desired length.

The critical welding machine instrument and control settings are considered confidential information and respected property of Armco Steel Company. All continuous welded seam pipe must, therefore, be considered acceptable or rejectable on its own merits based on nondestructive sampling substantiated with physical destructive testing as necessary and accompanied with the usual visual inspection.

V. TEST PROCEDURE

Samples, 24-inches by 24-inches and centered on the welded seam, were flame cut from lengths of production fabricated continuous welded seam pipes, involving different diameters, thicknesses of steel sheet, and heat numbers. Physical test specimens and micro-etched specimens were prepared from each sample in the number and type as follows:

No. Req.	Type
3	Tensile tests across the weld
3	Tensile tests of the base metal above the weld
3	Tensile tests of the base metal below the weld
3	Face bends
3	Root bends
3	Cup tests on the weld
3	Cup tests on the base metal
3	Micro-etch specimens of the weld cross section

The specimen layout on the sample was as shown in Figure 1.

Tensile Specimens

Tensile specimens were prepared to contain a 2-1/4 inch long 1/2 inch wide reduced section (see Figure 2). All tensile specimens contained 0.200 inch and 2.00 inch gage lengths on both sides and across the weld area (see Figure 3). The data resulting from the base metal and the "across the weld" tensile tests were:

a. The ultimate tensile load and ultimate tensile stress.

b. Percent elongation of both the face side and the root side of the weld (see Appendix A for all test data).

Face and Root Bend Specimens

All face and root bend specimens contained 0.200 inch gage marks on their appropriate sides across the weld area. The data resulting from the face and root bend tests for Tests #1 through #5 (see Appendix A) were the percent elongations of the gage lengths after guided bending around a 1/2 inch diameter

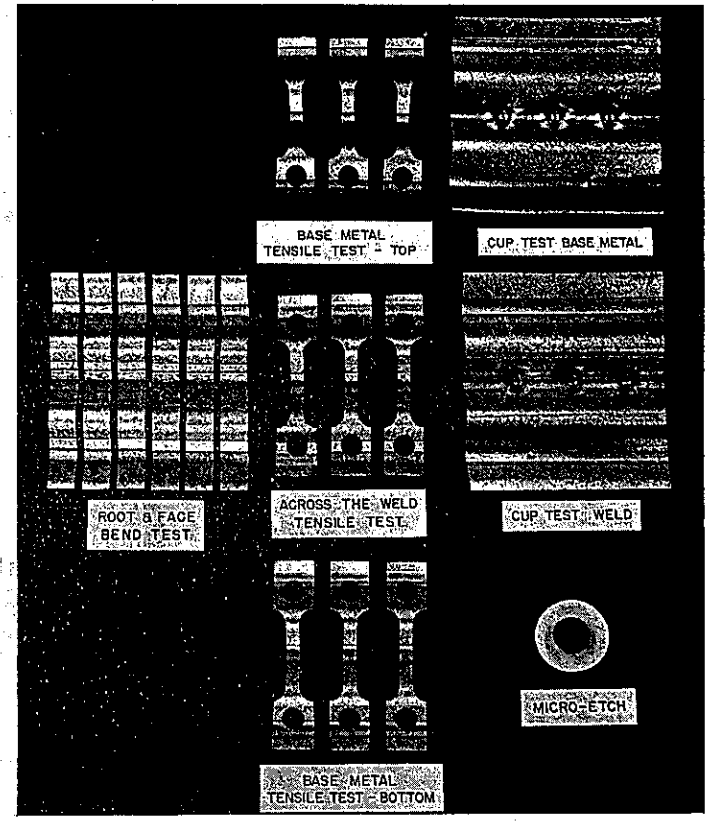


FIGURE 1
Welded Seam Test Specimens

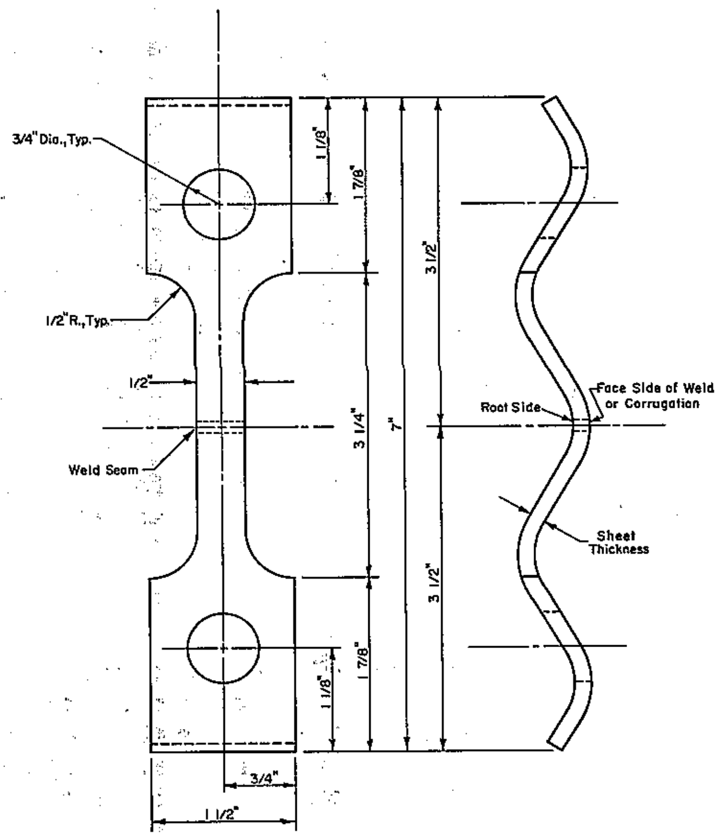


FIGURE 2
Tensile Test Specimen Drawing

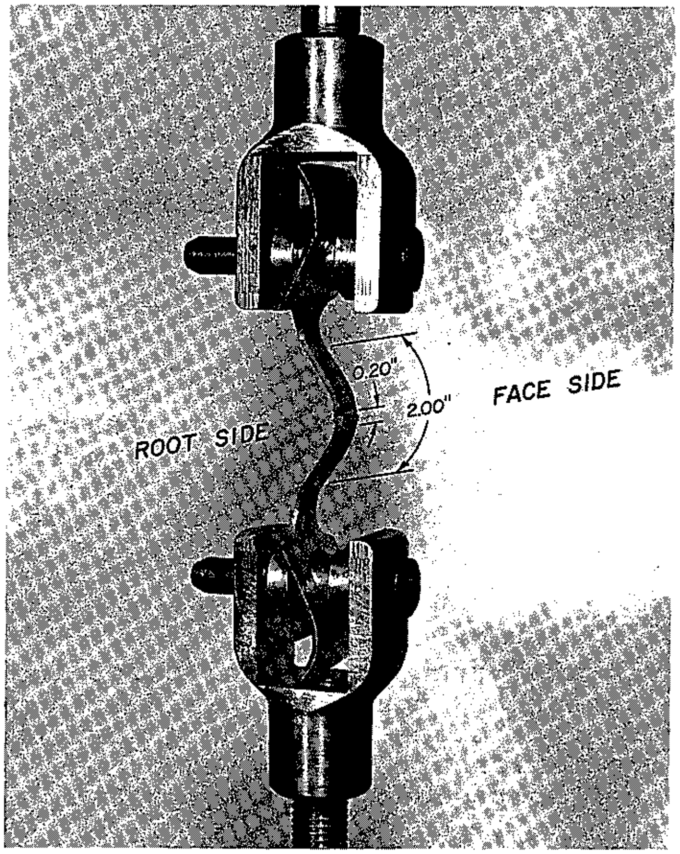


FIGURE 3
Tensile Test Fixturing and Gage Locations

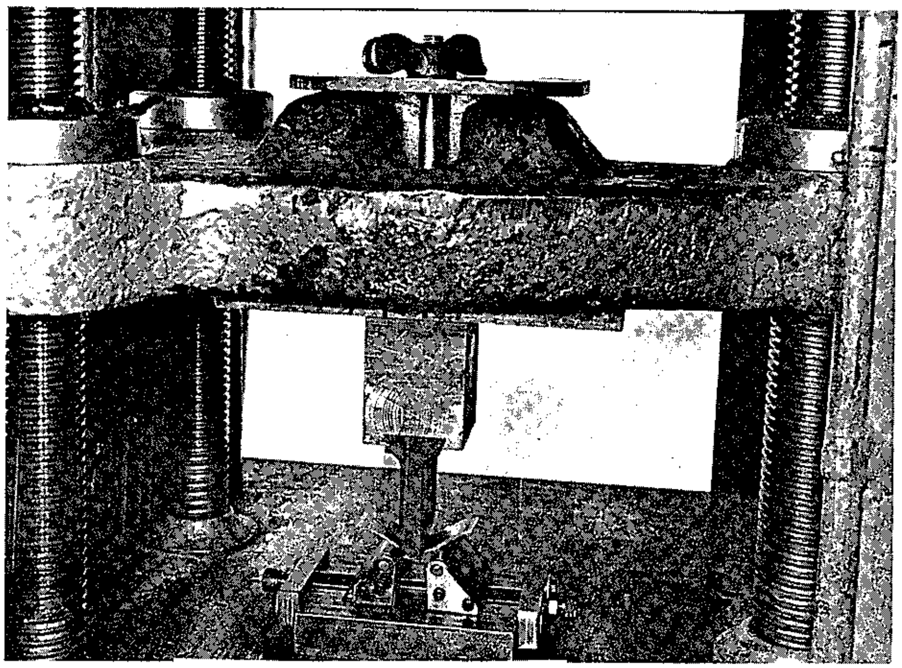


FIGURE 4
Face Bend Fixtures

mandrel (see Figure 4). After the fifth test, it was concluded from the resulting data that the root bend test as conducted was too severe to be representative of loads that would realistically develop in the pipe. Subsequent root bend specimens (Tests #6 through #17) were therefore tested by bending in the test fixture only to the flat position.

Cup Test Apparatus

The cup test apparatus consisted of two parts, (1) the die and (2) the punch. The die was steel and contained a 1-1/2 inch inside diameter relief. The die face was machined to conform to the corrugation of the pipe. The punch consisted of a 1 inch diameter steel ball brazed to a support fixture (see Figure 5). All tests and test data resulting from the use of this apparatus hereafter is referred to as the "cup test".

Cup Test on the Weld

All cup tests were centered on 0.200 inch gage lengths premarked at the center and across the weld area on both sides of the metal (face and root sides). The data resulting from the cup test were the percent elongation measured at the crown of the cup on both the face and root sides (see Figure 6).

Cup Test on the Base Metal

After the first five seam samples (Tests #1 through #5) were tested and evaluated, it was decided that the cup test should also be performed on the base material for comparison with the results on the welded seam. Therefore, three cup tests on the base metal were added to the standard physical testing program for Tests #6 through #17. These cup tests on the base metal also contained a 0.200 inch gage length premarked on both the face and root sides of the cup, across the crest of the corrugation, and centered at the crown of the cup. The data resulting from the cup test were the percent elongation evaluated on both the face and root sides of the cup.

Micro-Etched Specimens

Micro-etched specimens were taken from each of the test samples. These were secured from areas sufficiently removed from the flame cut edges of the samples that their micro-etched surfaces would contain grain sizes representative of the fusion welding process only. The specimens were placed in a plastic mounting, polished, and viewed under a microscope for possible weld joint defects such as lack of fusion, poor joint alignment, and cracking.

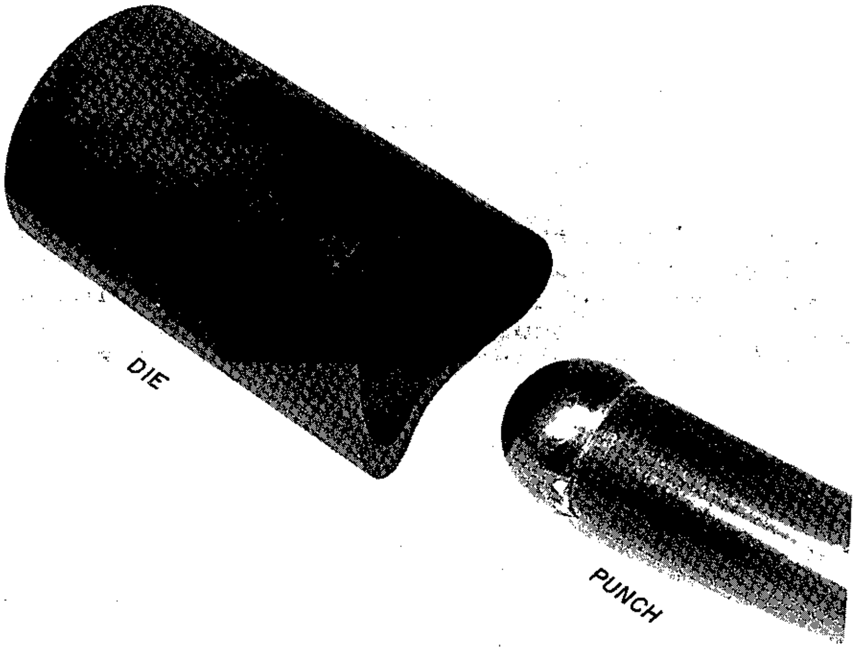


FIGURE 5
Die and Punch

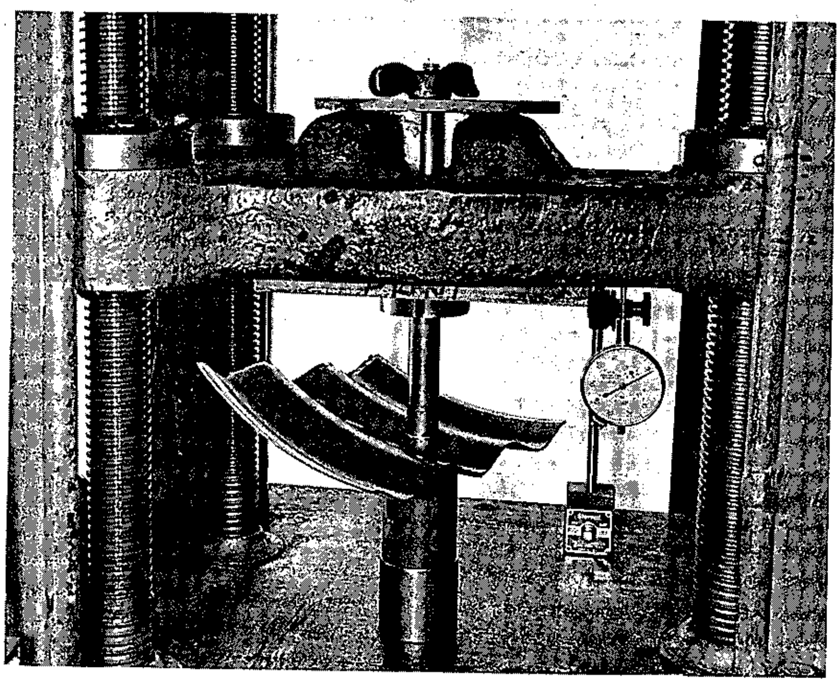


FIGURE 6
Cup Test Fixturing in Operation

VI. DISCUSSION

The tensile tests were performed on the specimens in the recognized standard fashion. After the specimens were machined to their testing configuration, their thicknesses and widths were accurately measured with both pointed and faced micrometers in order to accurately obtain the stress area. This area was used along with the ultimate tensile load to determine the ultimate tensile stress of the specimen. The only addition to the standard practice was 0.200 inch gage marks on the specimens.

The 2.00 inch gage marks were placed on both the root and face sides of the tensile specimens with the aid of a thin metal template. The template was of such a length that a scribed line at each end of the gage, whether the template was laying on a curved or flat surface, resulted in a 2.00 inch gage length. A similar technique was used for the 0.200 inch gage length. Whereas the 2.00 inch gage lengths were assumed to be true after scribing, the 0.200 inch gage lengths were measured with the aid of a filar eyepiece laboratory microscope (see Figure 7). The remaining bend tests and cup tests contained 0.200 inch gage lengths which were also measured before and after testing, using the filar eyepiece microscope. The elongation of the tensile specimens containing the 2.00 inch gage marks were measured with a standard engineering scale graduated in 1/100 inch units.

It was concluded that the most desirable nondestructive tests to insure weld quality requires that an area of the welded seam of the pipe be tested in tension without affecting the serviceability of the tested length of pipe. Preliminary analysis suggested that a "cup test" would supply the information desired and in a nondestructive fashion.

The suitability of the cup test for determining the acceptability of the welded seam in the pipe in lieu of extracting the test coupon was, at the beginning of this project, still questionable. Two primary questions were asked:

1. In which direction should the cup test impression or dimple be performed, i.e., with the concavity of the corrugation or opposite in direction to the concavity of the corrugation?

2. What depth of cup or dimple represents an assurance level that the welded seam is satisfactorily fused?

An 8 to 10 percent permanent elongation of the 0.200 inch gage length across the weld area without failure was defined by the project investigators as indicative of satisfactory fusion.

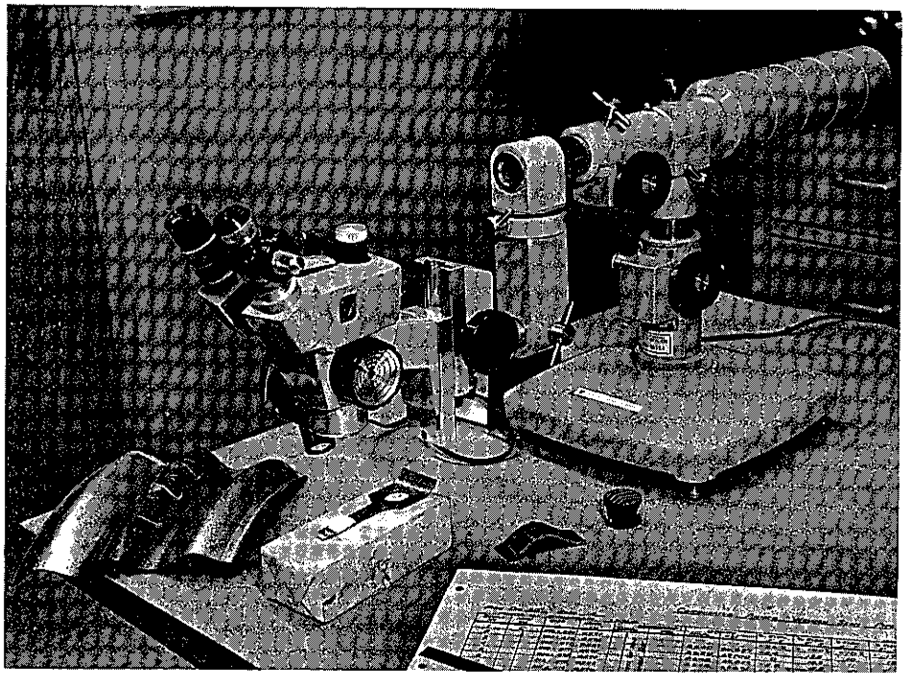


FIGURE 7
Measuring Microscope

VII. DATA ANALYSIS

The "across the weld" tensile test data and the base metal tensile test data were analyzed for comparable strengths. This information along with the observance of certain "across the weld" tensile test specimens failing under ultimate load outside the weld zone (clearly in the adjoining base material) showed that a welded seam could exhibit strength equal to and even exceeding the base metal strength.

The "face bend" and the "root bend" testing data were obtained to complement the tensile test data in an effort to determine over-all weld seam quality. Both tests result in valuable information regarding face and root fusion.

Early investigations of the cup test revealed that when the test was performed in the direction of the concavity of the corrugation, it induced positive elongation across the complete weld section (both sides). This test was performed on preliminary samples of 14 gage, 30 inch diameter welded seam pipe (see Figure 8). The results of this test which placed the complete weld in tension tentatively indicated that a cup test performed in the direction of the concavity of the corrugation would provide the most constructive information on the welded seam.

It was not until later in the testing program that the direction of the cup test was reversed. The results of the cup test where the testing was opposite to the direction of the concavity of the corrugations are shown in Figure 9. These are similar to the results obtained in a root bend test, i.e., the root elongations are positive while the face elongations are negative. The test data for generating the two curves in Figure 9 required 384 separate measurements, half were associated with the face gage marks and the remaining half with the root gage marks. The data plotted in Figure 9 represent the averaging of elongations of each of 12 separate cup tests.

Based on the results of cup tests performed in both directions, it was concluded that a cup test performed in the direction of the concavity of the corrugation was a more positive over-all indicator of a satisfactory weld. Therefore, all of the pipe samples (Tests #1 through #17) were cup tested in this direction.

After the first five pipe samples were tested (Tests #1 through #5), it was recognized that cup tests at the selected depth of 1/4 inch were inducing elongation across the weld generally exceeding those obtained from the tensile tests. The decision was made, after carefully reviewing the information obtained in all previous tests, to relax the depth to 3/16 inch.

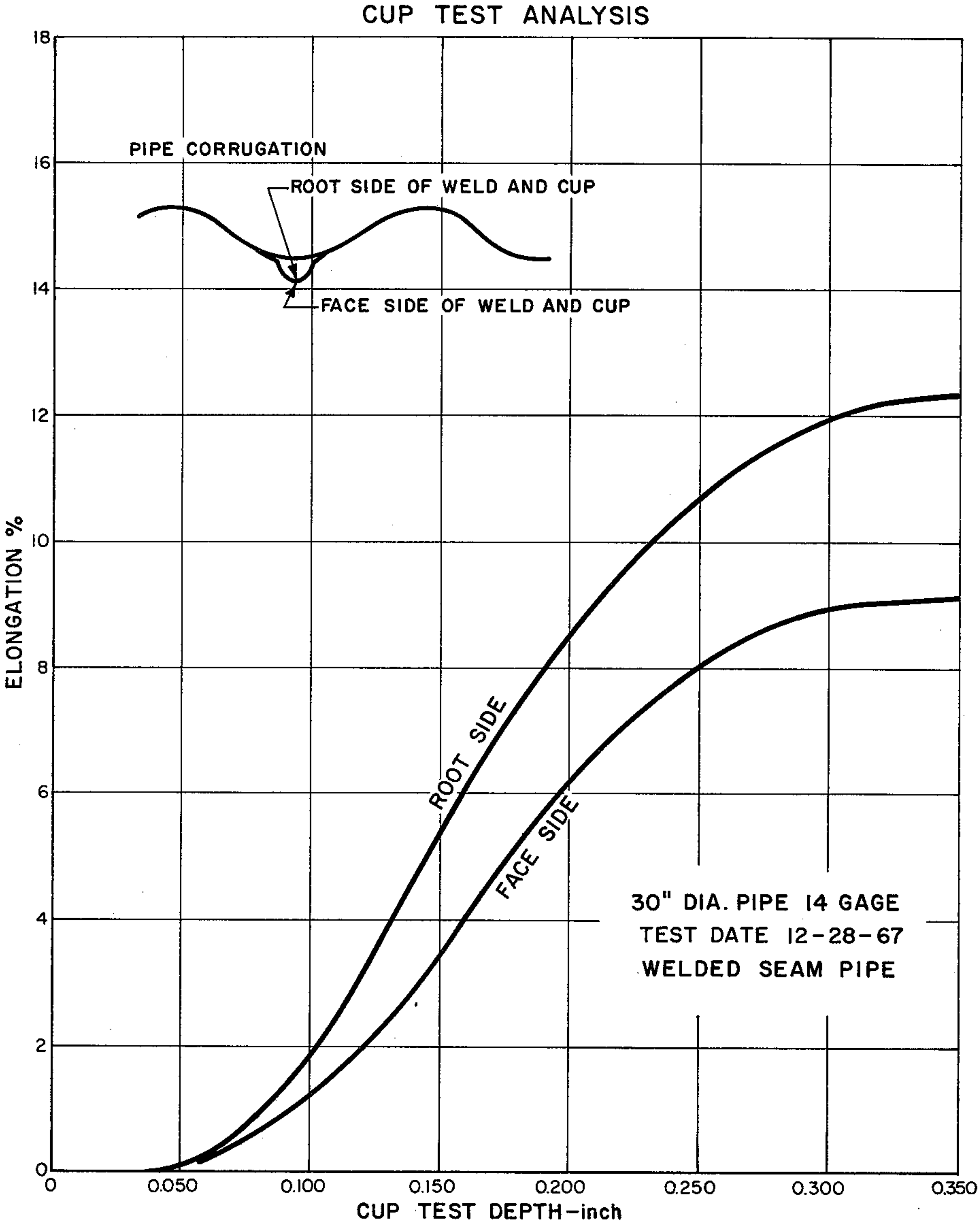


FIGURE 8
Preliminary Cup Test Data
(Cupped in same direction as corrugation)

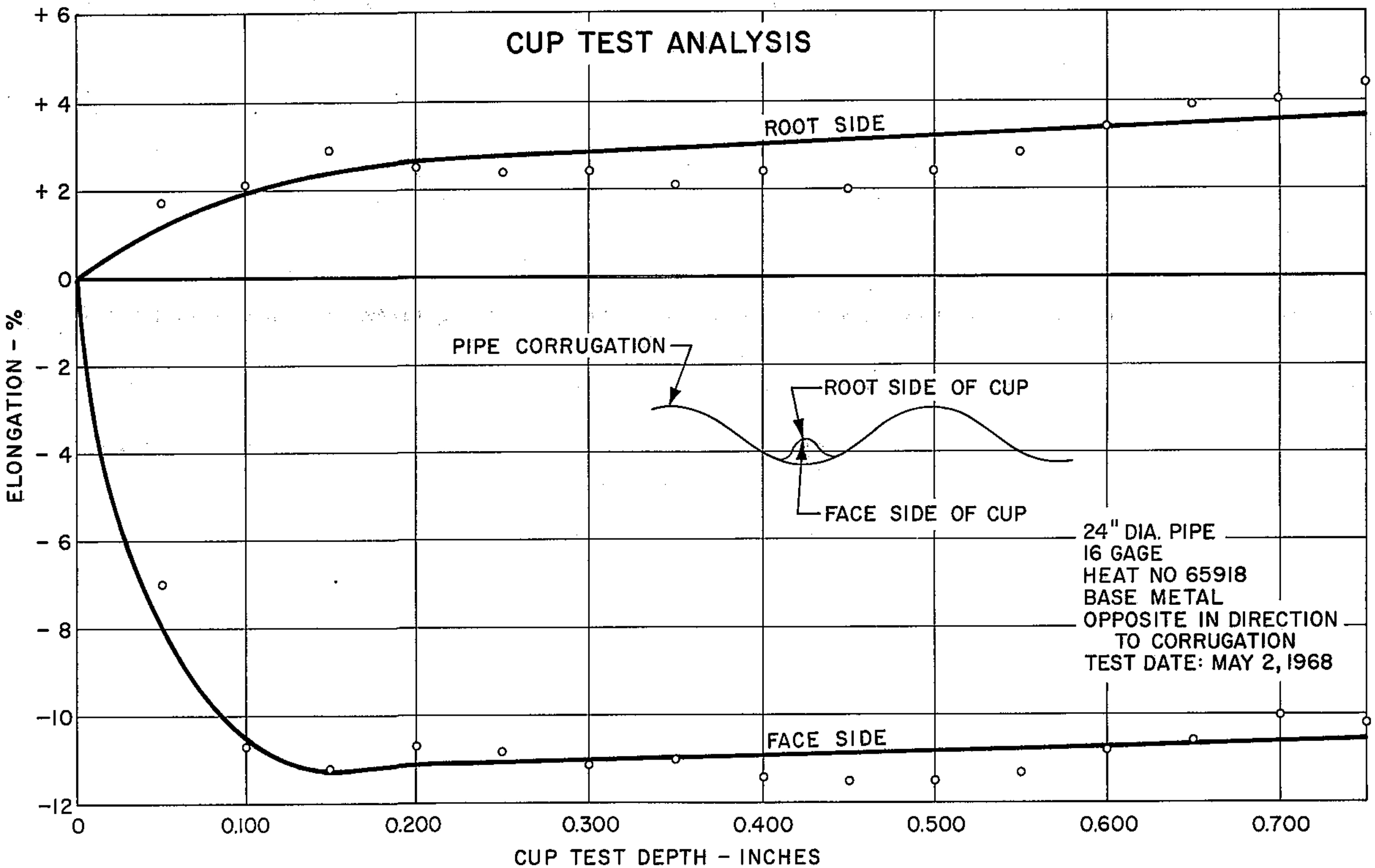


FIGURE 9
Preliminary Cup Test Data
(Cupped in opposite direction to the corrugation)

The 3/16 inch cup test under load resulted in a realistic value of 8 to 10 percent permanent elongation across the weld seam. Up to the time of this report, eleven subsequent tests have corroborated the 3/16 inch cup test under load as a realistic depth for assuring seam quality for continuous welded seam pipe.

Although the test data on welded seam samples from 8 and 10 gage pipe is limited, we are optimistic that elongations obtained from the 3/16 inch cup test under load will continue to be uninfluenced by pipe metal thicknesses.

The data resulting from Test #6, involving a sample of 36 inch diameter, 14 gage, continuous welded seam pipe, looks contradictory, i.e., the "across the weld" tensile test data was acceptable whereas the "cup test" data in the weld seam shows failure. Close examination of micro-etched specimens from the weld seam in the area of the tensile specimens revealed the joint to be offset. A second micro-etched specimen taken from the area of the weld seam of the cup test specimen revealed a weld seam with an even greater joint offset. The conclusion that joint offset was the cause of failure documents the degree of joint offset or misalignment that will result in inadequate joint strength. Figure 10 shows the micro-etched specimen (micrograph) taken from the area of the "across the weld tensile test" specimens of Test #6. Figure 11 shows the micrograph of the specimen taken from the area of the "cup test" specimens for the same test (note the greater joint offset of Figure 11).

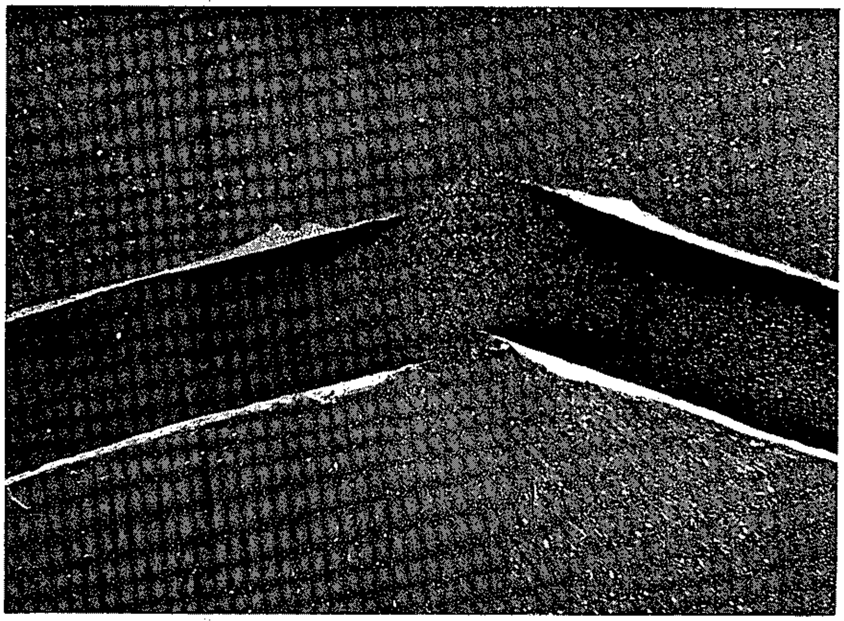


FIGURE 10
Micrograph of Joint Geometry Taken
From Near the Tensile Test Specimens

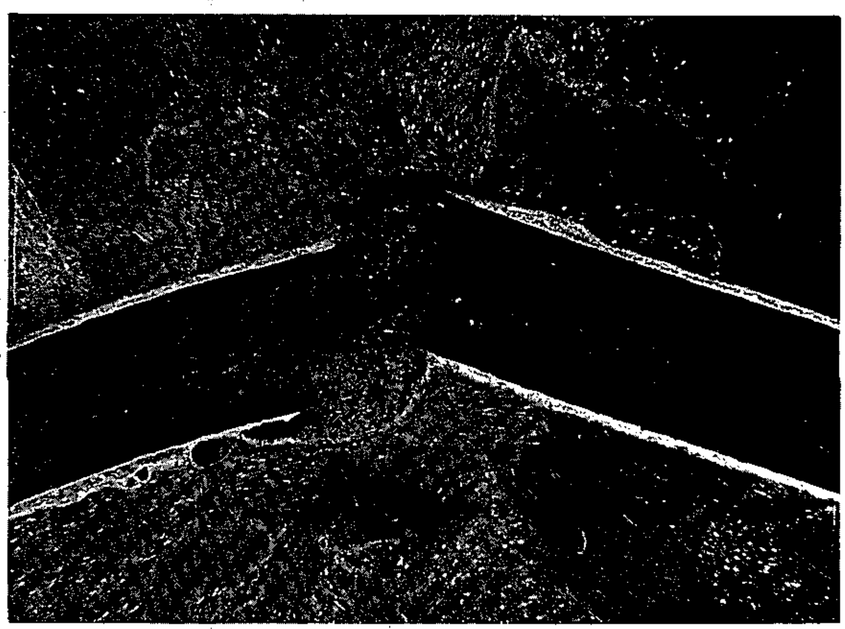


FIGURE 11
Micrograph of Joint Geometry Taken
From Near the Cup Test Specimens

VIII. QUALITY CONTROL TEST METHOD

As the result of this investigation, a control procedure to assure the quality of the continuous welded seam in helically corrugated galvanized steel pipe was tentatively established. This procedure is described in Test Method No. Calif. T665-B, dated March 15, 1969 (see Appendix B).

This test method specifies that the punch will be forced into the welded seam to obtain a residual cup deflection (dimple depth) of at least 1/8 inch. Test experience to date indicates that, allowing for metal spring back, a residual cup deflection of 1/8 inch is comparable to the 3/16 inch cup deflection, under load, employed in the laboratory investigation.

The California Division of Highways Standard Specifications dated January 1969 now qualify continuous helical welded seam galvanized steel pipe as follows:

> "Pipe fabricated with a helical welded seam parallel to the corrugations may be used for full circle and equivalent pipe-arch sizes. The welding process shall be so controlled that the combined width of the weld and adjacent spelter coating burned by the welding does not exceed 3 times the thickness of the metal. If spelter is damaged by the welding outside of the specified area, the weld and damaged spelter adjacent to the weld shall be cleaned and painted as specified in Section 55-3.28, 'Galvanizing'. Testing for welded seam quality control shall conform to Test Method No. Calif. 665."

APPENDIX A

#1

Pipe Diameter = 24" Pipe Gage = 14 Heat Number 272416

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.504	.076	.03830	2,150	56,140	- 1.5%	+10.2%	+12%	+17%	
	2	.505	.075	.03787	2,140	56,510	- 1.4	10.4	13	20	
	3	.505	.075	.03787	2,170	57,300	- 1.4	11.7	12	18	
Base Metal Tensile Test Top	4	.503	.072	.03622	2,130	58,810	+ 1.3	10.1	17	21	
	5	.503	.071	.03571	2,150	60,210	+ 0.6	11.2	20	25	
	6	.510	.072	.03672	2,130	58,010	- 2.7	8.7	13	18	
Base Metal Tensile Test Bottom	7	.509	.075	.0382	2,150	56,280	0.0	9.4	18	23	
	8	.508	.075	.0381	2,140	56,170	- 1.7	8.9	17	22	
	9	.507	.075	.0380	2,130	56,050	+ 0.7	11.2	20	25	
Face Bend Test	10						+ 5.2%				
	11						+ 5.6				
	12						+ 7.7				
Root Bend Test	13							+22.3%			
	14							17.8			
	15							25.0			
Cup Test Weld	16	@1/4"					+ 8.7	11.7			
	17	"					+10.0	15.0			
	18	"					+ 9.0	14.0			
Cup Test Base Metal	19										No test specimen
	20										No test specimen
	21										No test specimen
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#2 Pipe Diameter = 15" Pipe Gage = 16 Heat Number 127409

TEST TYPE	SPECIMEN NUMBER	SIZE		AREA IN^2	ULTIMATE		% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
		WIDTH	THICKNESS		LOAD	STRESS					
Across the Weld Tensile Test	1 2 3	.505 .504 .510	.060 .061 .060	.0303 .0307 .0306	1,775 1,790 1,725	58,580 58,300 56,370	+ 2.6% + 3.4 *	+21.2% 24.9 *	+ 9% 10 0	+16% 16 8	*Failed in weld
Base Metal Tensile Test Top	4 5 6	.503 .510 .503	.061 .060 .061	.0307 .0306 .0307	1,770 1,795 1,775	57,650 58,660 57,820	+ 0.7 + 6.2 .0	10.5 15.7 7.7	15 15 14	20 19 18	
Base Metal Tensile Test Bottom	7 8 9	.504 .504 .505	.061 .061 .061	.0307 .0307 .0308	1,750 1,770 1,770	57,000 57,650 57,470	- 1.0 + 4.4 **	6.8 12.3 **	15 15 15	20 20 20	** No data
Face Bend Test	10 11 12						+ 2.6% + 4.0 + 2.7				
Root Bend Test	13 14 15							+27.0% 27.2 28.2			
Cup Test Weld	16 17 18	@ 1/4" " "					* +12.6 +19.0	* 23.3 26.6			* Failed in weld
Cup Test Base Metal	19 20 21										No test specimen " " " " " "
Micro-Etch	22 23 24										O.K. O.K. O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#3

Pipe Diameter = 12"   Pipe Gage = 16   Heat Number 471V002

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.492	.059	.0290	1,755	60,480	- 5.9%	+10.4%	+ 7%	+15%	
	2	.516	.059	.0290	1,830	62,990	-10.5	9.9	8	16	
	3	.510	.059	.0290	1,835	63,170	- 2.4	8.4	8	15	
Base Metal Tensile Test Top	4	.471	.059	.0301	1,730	57,490	- 7.7	8.4	12	17	
	5	.504	.059	.0297	1,850	62,230	- 1.4	7.4	11	16	
	6	.501	.058	.0290	1,840	63,340	- 3.2	6.8	11	16	
Base Metal Tensile Test Bottom	7	.503	.059	.0297	1,805	60,770	0.0	6.9	12	17	
	8	.524	.059	.0390	1,790	57,930	-0.8	6.8	9	15	
	9	.501	.058	.0290	1,780	61,270	-2.3	5.7	11	16	
Face Bend Test	10						+2.0%				
	11						+1.8				
	12						+5.5				
Root Bend Test	13							+14.2%			
	14							**			** No data
	15							17.1			
Cup Test Weld	16	@1/4"					+9.2	7.9			
	17	"					+8.7	10.4			
	18	"					+12.0	9.4			1/4" Face Split
Cup Test Base Metal	19										No test specimen
	20										" " "
	21										" " "
Micro-Etch	22										Crack at face of weld
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory					☐ Unsatisfactory					

#4

Pipe Diameter = 18" Pipe Gage = 16 Heat Number 127409

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.523	.059	.03086	1,865	60,430	+ 1.6%	+18.5%	+ 6%	+14%	
	2	.513	.058	.02975	1,850	62,180	+ 1.3	20.9	9	15	
	3	.494	.060	.02964	1,790	60,390	+ 1.7	19.9	8	15	
Base Metal Tensile Test Top	4	.510	.059	.03009	1,850	61,480	+ 1.9	12.1	13	20	
	5	.505	.059	.03039	1,860	61,200	*	*	15	20	*Failed @ 0.2" Gage Mark
	6	.502	.060	.03012	1,840	61,090	+ 0.6	5.7	13	17	
Base Metal Tensile Test Bottom	7	.508	.060	.03048	1,810	59,380	- 0.6	8.7	9	16	
	8	.517	.058	.02998	1,790	59,710	- 1.3	6.3	12	16	
	9	.515	.060	.03090	1,850	59,870	+ 2.5	12.8	12	17	
Face Bend Test	10						+ 4.1%				
	11						+ 4.1				
	12						+ 3.9				
Root Bend Test	13							30.8%			
	14							21.0			
	15							26.4			
Cup Test Weld	16	@ 1/4"					+10.2%	20.2			
	17	"					+11.1	19.5			
	18	"					+12.8	23.5			
Cup Test Base Metal	19										No Test Specimen
	20										" " "
	21										" " "
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#5

Pipe Diameter = 24"　　Pipe Gage = 16　　Heat Number 65918

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1 2 3	.502 .500 .507	.059 .059 .058	.0296 .0295 .0294	1,710 1,740 1,735	57,770 58,980 59,010	- 2.4% - 1.0 - 3.5	+ 8.6% + 7.7 +10.6	+10% 12 10	+18% 20 17	
Base Metal Tensile Test Top	4 5 6	.508 .507 .503	.058 .057 .057	.0295 .0289 .0287	1,700 1,690 1,690	57,630 58,480 58,890	- 1.2 0.0 - 0.8	+ 5.3 + 7.9 + 3.9	13 12 12	18 17 17	
Base Metal Tensile Test Bottom	7 8 9	.508 .510 .496	.058 .058 .059	.0295 .0296 .0293	1,730 1,730 1,705	58,640 58,450 58,190	0.0 + 0.4 - 0.4	+ 8.5 + 7.0 + 6.3	14 14 12	19 18 16	
Face Bend Test	10 11 12						+ 3.8% + 4.1 + 4.2				
Root Bend Test	13 14 15							+10.2% + 8.5 16.2			
Cup Test Weld	16 17 18	@ 1/4" " "					+ 7.7% 12.5 11.3	+17.5 15.4 18.5			
Cup Test Base Metal	19 20 21										No test specimen " " " " " "
Micro-Etch	22 23 24										O.K. Small Face Crack O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#6

Pipe Diameter = 36"   Pipe Gage = 14   Heat Number 490S5261

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.502	.077	.0387	2,130	55,040	- 3.4%	+18.2%	* *	* *	* * No Data
	2	.504	.077	.0388	2,120	54,640	- 2.2	17.8	* *	* *	* * " "
	3	.504	.077	.0388	2,090	53,860	- 3.5	17.8	* *	* *	" "
Base Metal Tensile Test Top	4	.505	.075	.0379	2,115	55,800	- 1.9	10.5	* *	* *	* * No Data
	5	.499	.075	.0374	2,130	56,950	- 1.8	9.7	* *	* *	" "
	6	.502	.074	.0371	2,140	57,680	0.0	9.2	* *	* *	" "
Base Metal Tensile Test Bottom	7	.497	.075	.0373	2,090	56,030	+10.9	19.7	* *	* *	* * No Data
	8	.500	.075	.0375	2,100	56,000	+ 4.8	11.3	* *	* *	" "
	9	.506	.074	.0374	2,110	56,420	+ 3.3	9.5	* *	* *	" "
Face Bend Test	10						+ 3.1%				
	11						+ 3.9				
	12						+ 4.4				
Root Bend Test	13							+30.9%			
	14							38.6			
	15							41.0			
Cup Test Weld	16	@3/16"					+12.4%	17.0			
	17	"					*	*			* Failed in weld
	18	"					*	*			*Failed in weld
Cup Test Base Metal	19	@3/16"					+ 8.2	+ 2.3			
	20	"					+ 8.7	+ 1.7			
	21	"					+ 8.7	+ 1.4			
Micro-Etch	22										Offset Joint
	23										Offset Joint
	24										Offset Joint
Test Results	☐ Satisfactory						☒ Unsatisfactory				

#7

Pipe Diameter = 42" Pipe Gage = 12 Heat Number 471W0012

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.501	.109	.0546	2,990	54,760	- 3.4%	+22.9%	+13%	+26%	
	2	.507	.109	.0553	2,960	53,560	- 5.8	12.2	13	26	
	3	.502	.108	.0554	2,965	54,680	- 2.7	16.3	11	23	
Base Metal Tensile Test Top	4	.504	.103	.0519	2,920	56,260	- 2.6	13.7	18	24	
	5	.503	.100	.0503	2,920	58,050	- 1.9	13.7	16	23	
	6	.505	.103	.0520	2,920	56,150	- 2.6	13.7	17	24	
Base Metal Tensile Test Bottom	7	.505	.100	.0505	2,940	58,220	- 1.0	14.5	21	21	
	8	.502	.101	.0507	2,890	57,000	- 2.6	12.6	21	21	
	9	.504	.101	.0509	2,910	57,170	- 1.5	11.0	22	22	
Face Bend Test	10						+12.4%				
	11						6.7				
	12						11.2				
Root Bend Test	13							+41.7%			
	14							*			*Failed in Weld
	15							32.3			
Cup Test Weld	16	@ 3/16"					+14.7	+ 7.6			
	17	"					3.0	15.3			
	18	"					13.6	16.7			
Cup Test Base Metal	19	@3/16"					11.3	3.1			
	20	"					8.9	4.6			
	21	"					7.4	5.8			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory					☐ Unsatisfactory					

#8

Pipe Diameter = 48"   Pipe Gage = 12   Heat Number 471W0012

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN²	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.500	.105	.0525	3,100	59,050	- 2.0%	+23.5%	+16%	+24%	
	2	.505	.107	.0540	3,070	56,850	- 3.7	22.4	12	20	
	3	.501	.109	.0541	3,100	57,300	- 3.2	25.0	13	23	
Base Metal Tensile Test Top	4	.503	.101	.0508	3,230	63,580	- 2.9	12.6	13	20	
	5	.502	.102	.0512	3,210	62,700	- 3.2	14.0	13	18	
	6	.498	.102	.0508	3,200	63,000	- 3.2	12.5	15	20	
Base Metal Tensile Test Bottom	7	.501	.101	.0506	3,200	63,240	- 1.3	12.5	13	18	
	8	.497	.100	.0497	3,180	63,980	- 1.0	13.8	12	18	
	9	.502	.100	.0502	3,180	63,350	- 2.1	10.8	14	16	
Face Bend Test	10						+ 2.6%				
	11						9.4				
	12						7.6				
Root Bend Test	13							+46.8%			
	14							48.4			
	15							44.0			
Cup Test Weld	16	@ 3/16"					+ 9.0%	+14.0%			
	17	"					6.4	12.5			
	18	"					6.0	12.3			
Cup Test Base Metal	19	@ 3/16"					4.9	6.0			
	20	"					6.7	5.0			
	21	"					9.4	4.8			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#9 Pipe Diameter = 48" Pipe Gage = 14 Heat Number 471W0009

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.496	.076	.0377	2,170	57,560	- 2.0%	+13.0%	+13%	21%	
	2	.501	.076	.0381	2,170	56,960	- 0.3	13.0	13	19	
	3	.504	.077	.0388	2,170	55,930	- 4.0	12.0	13	18	
Base Metal Tensile Test Top	4	.495	.072	.0356	2,260	63,480	- 3.0	+10.0	14	20	
	5	.503	.074	.0372	2,280	61,290	- 2.0	8.0	13	18	
	6	.500	.074	.0370	2,270	61,350	- 3.0	11.0	13	15	
Base Metal Tensile Test Bottom	7	.495	.074	.0366	2,360	64,480	0.0	8.0	12	16	
	8	.501	.074	.0371	2,380	64,150	- 0.3	5.0	11	17	
	9	.500	.073	.0365	2,370	64,930	0.0	7.0	13	18	
Face Bend Test	10						+ 5.7%				
	11						6.5				
	12						6.1				
Root Bend Test	13							+29%			
	14							31			
	15							*			* No Data
Cup Test Weld	16	@ 3/16"					+ 9.4%	+6.9%			
	17	"					9.7	9.2			
	18	"					10.1	12.3			
Cup Test Base Metal	19	@ 3/16"					9.2	3.8			
	20	"					10.4	6.2			
	21	"					12.3	8.4			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#10 Pipe Diameter = 36" Pipe Gage = 12 Heat Number 78495A

TEST TYPE	SPECIMEN NUMBER	SIZE		AREA IN^2	ULTIMATE		% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
		WIDTH	THICKNESS		LOAD	STRESS					
Across the Weld Tensile Test	1	.502	.105	.0527	3,630	68,880	- 3.0%	+15.8%	+ 7%	+18%	
	2	.501	.102	.0511	3,660	71,630	- 2.2	17.3	9	18	
	3	.501	.105	.0526	3,610	68,630	- 3.7	17.0	10	18	
Base Metal Tensile Test Top	4	.499	.100	.0499	3,610	72,350	0.0	13.9	11	16	
	5	.502	.101	.0507	3,620	71,400	- 3.2	13.9	11	16	
	6	.504	.097	.0489	3,650	74,640	- 2.8	12.6	10	16	
Base Metal Tensile Test Bottom	7	.490	.100	.0490	3,610	73,670	- 0.3	15.0	13	19	
	8	.504	.100	.0504	3,680	73,010	- 2.2	11.8	12	18	
	9	.499	.099	.0494	3,670	74,290	- 0.6	+11.4	11	17	
Face Bend Test	10						+ 8.6%				
	11						9.1				
	12						6.2				
Root Bend Test	13							+23.2%			
	14							34.0			
	15							30.0			
Cup Test Weld	16	@3/16"					+ 7.8	13.3			
	17	"					6.0	11.3			
	18	"					8.2	9.5			
Cup Test Base Metal	19	@3/16"					8.4	1.9			
	20	"					5.9	1.9			
	21	"					9.2	1.9			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#11

Pipe Diameter = 60"　　Pipe Gage = 12　　Heat Number 471W0025

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.503	.109	.0548	3,130	57,120	- 0.7%	+17.6%	+12%	+22%	
	2	.502	.109	.0547	3,110	56,860	- 3.1	17.4	13	20	
	3	.502	.109	.0547	3,110	56,860	- 0.7	17.6	13	21	
Base Metal Tensile Test Top	4	.503	.102	.0513	3,390	66,080	- 4.0	13.5	11	15	
	5	.499	.103	.0513	3,360	65,500	- 2.0	14.1	11	17	
	6	.502	.103	.0517	3,400	65,770	- 4.0	12.0	10	16	
Base Metal Tensile Test Bottom	7	.497	.101	.0502	3,430	68,330	*	*	9	14	*Failed @ 0.2" Gage Mark
	8	.502	.101	.0507	3,460	68,250	- 0.2	14.6	11	17	
	9	.505	.102	.0515	3,480	67,570	*	*	8	15	*Failed @ 0.2" Gage Mark
Face Bend Test	10						+ 4.2%				
	11						5.8				
	12						7.9				
Root Bend Test	13							+29.0%			
	14							23.0			
	15							22.0			
Cup Test Weld	16	@3/16"					+10.8	8.8			
	17	"					8.8	9.2			
	18	"					10.0	10.1			
Cup Test Base Metal	19	@3/16"					7.1	1.8			
	20	"					5.1	2.8			
	21	"					7.4	2.1			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory					☐ Unsatisfactory					

#12

Pipe Diameter = 30"   Pipe Gage 16   Heat Number 471W0042

TEST TYPE	SPECIMEN NUMBER	SIZE		AREA IN^2	ULTIMATE		% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
		WIDTH	THICKNESS		LOAD	STRESS					
Across the Weld Tensile Test	1	.510	.063	.0321	1,760	54,830	- 0.7%	+13.8%	+10%	+18%	
	2	.509	.063	.0321	1,760	54,830	- 1.4	9.8	11	15	
	3	.499	.061	.0304	1,740	57,240	- 9.7	12.1	11	16	
Base Metal Tensile Test Top	4	.500	.061	.0305	1,750	57,380	- 3.7	6.8	10	18	
	5	.510	.061	.0311	1,750	56,270	- 1.7	5.8	11	15	
	6	.512	.060	.0307	1,790	58,310	- 3.2	5.8	10	16	
Base Metal Tensile Test Bottom	7	.510	.061	.0311	1,795	57,720	- 2.2	5.9	11	15	
	8	.500	.060	.0300	1,775	59,170	- 0.2	8.9	11	16	
	9	.505	.061	.0308	1,780	57,790	- 2.4	8.1	10	16	
Face Bend Test	10						+3.3%				
	11						1.5				
	12						7.7				
Root Bend Test	13							+20.5			
	14							18.4			
	15							20.1			
Cup Test Weld	16	@3/16"					+14.9	11.2			
	17	"					13.2	13.3			
	18	"					8.8	19.1			
Cup Test Base Metal	19	@3/16"					5.3	4.9			
	20	"					9.2	4.7			
	21	"					7.8	4.0			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

#13

Pipe Diameter = 30"   Pipe Gage 14   Heat Number 471W0042

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.503	.078	.0392	2,250	57,400	- 7.7%	*	+ 8%	+15%	* No Data
	2	.503	.078	.0392	2,240	57,140	*	*	7	18	" "
	3	.504	.078	.0393	2,250	57,250	*	+12.5%	8	18	" "
Base Metal Tensile Test Top	4	.502	.077	.0387	2,270	58,660	*	16.8	10	15	* No Data
	5	.506	.078	.0394	2,270	57,610	+ 2.5	*	15	15	" "
	6	.505	.078	.0394	2,275	57,740	- 5.5	*	12	18	" "
Base Metal Tensile Test Bottom	7	.498	.075	.0374	2,245	60,030	- 3.6	16.1	13	17	
	8	.508	.077	.0391	2,300	58,820	*	*	13	18	* No Data
	9	.510	.075	.0383	2,295	60,000	-12.4	+ 7.1	14	18	
Face Bend Test	10						+ 4.9%				
	11						3.3				
	12						3.8				
Root Bend Test	13							+20.1%			
	14							26.5			
	15							23.6			
Cup Test Weld	16	@ 3/16"					+17.5	17.8			
	17	"					16.3	18.0			
	18	"					5.1	24.8			
Cup Test Base Metal	19	@ 3/16"					10.7	3.3			
	20	"					11.4	1.0			
	21	"					9.5	0.2			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory				☐ Unsatisfactory						

#14

Pipe Diameter = 72"   Pipe Gage = 8   Heat Number 471W0055

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.505	.161	.0813	4,950	60,860	- 4.5%	+ 19.5%	0%	+ 10%	
	2	.503	.163	.0820	4,970	60,610	- 6.3	19.8	0	10	
	3	.505	.163	.0823	4,920	59,780	- 0.7	15.1	0	15	
Base Metal Tensile Test Top	4	.503	.162	.0815	5,050	61,960	*	*	+ 8%	15	*Failed @ 0.2" Gage Mark
	5	.502	.158	.0793	5,000	63,050	*	*	10	15	" " " "
	6	.495	.158	.0782	4,870	62,280	*	*	5	13	" " " "
Base Metal Tensile Test Bottom	7	.501	.157	.0787	4,870	61,880	*	*	8	15	*Failed @ 0.2" Gage Mark
	8	.508	.157	.0798	4,920	61,650	*	*	8	15	" " " "
	9	.499	.159	.0793	4,910	61,920	*	*	8	15	" " " "
Face Bend Test	10						+20.1%				
	11						11.5				
	12						18.9				
Root Bend Test	13							+41.3%			
	14							46.9			
	15							43.4			
Cup Test Weld	16	@ 3/16"					+ 7.1	11.2			
	17	"					13.4	7.9			
	18	"					9.4	8.4			
Cup Test Base Metal	19	@ 3/16"					9.9	1.9			
	20	"					11.0	4.0			
	21	"					11.8	3.9			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory					☐ Unsatisfactory					

#15

Pipe Diameter = 72" Pipe Gage = 10 Heat Number 491W2431

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.508	.138	.0701	4,045	57,700	- 4.2%	+17.4%	- 4%	+ 9%	
	2	.506	.138	.0698	4,015	57,520	- 5.4	16.9	- 4	9	
	3	.508	.138	.0701	4,095	58,420	- 5.2	18.5	- 4	9	
Base Metal Tensile Test Top	4	.500	.132	.0660	3,950	59,850	*	*	+ 8	15	*Failed @ 0.2" Gage Mark
	5	.505	.132	.0667	3,980	59,670	+ 1.1	+21.4	4	11	
	6	.503	.132	.0664	3,965	59,710	*	*	9	15	*Failed @ 0.2" Gage Mark
Base Metal Tensile Test Bottom	7	.508	.140	.0711	4,365	61,390	*	*	6	13	*Failed @ 0.2" Gage Mark
	8	.507	.140	.0710	4,350	61,270	*	*	7	14	" " " " "
	9	.499	.140	.0699	4,300	61,520	*	*	7	14	" " " " "
Face Bend Test	10						+10.3%				
	11						13.0				
	12						8.3				
Root Bend Test	13							+22.0%			
	14							26.9			
	15							27.8			
Cup Test Weld	16	@ 3/16"					+ 8.5	11.8			
	17	"					11.2	14.5			
	18	"					4.3	9.7			
Cup Test Base Metal	19	@ 3/16"					+ 9.4	11.7			
	20	"					11.0	8.7			
	21	"					10.8	7.7			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results		☒ Satisfactory					☐ Unsatisfactory				

#16

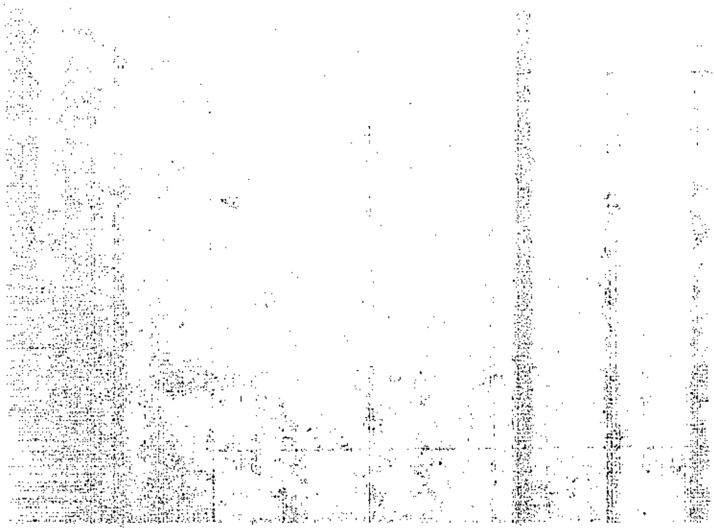
Pipe Diameter = 54"　　Pipe Gage = 12　　Heat Number 471W0031

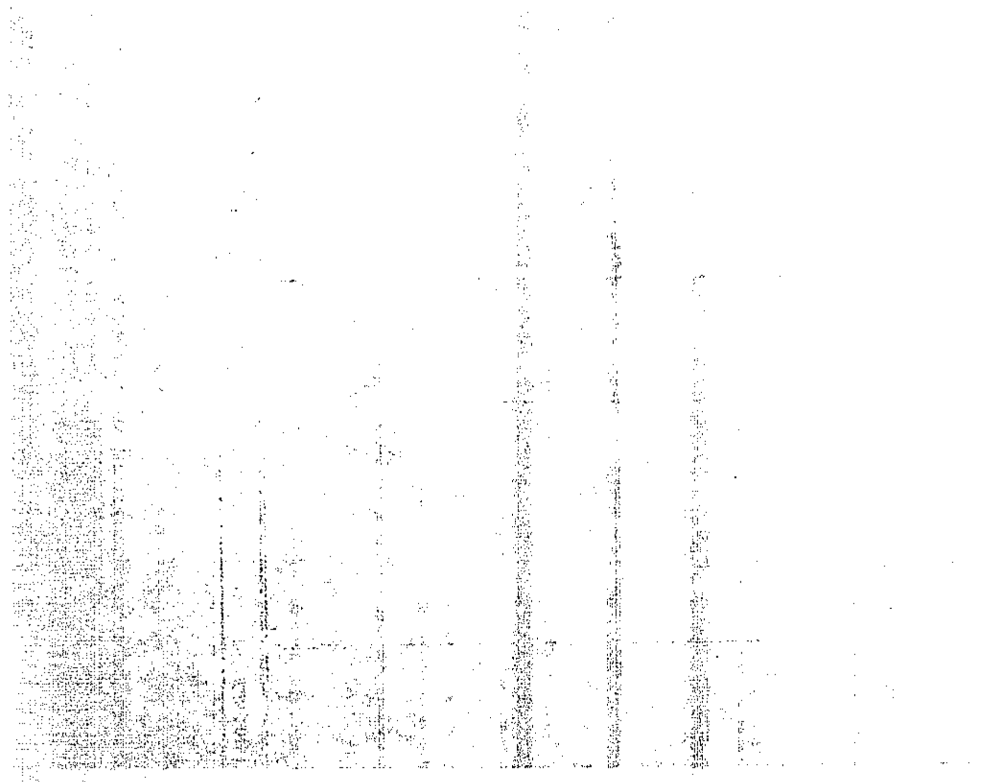
TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.505	.110	.0556	3,015	54,230	- 2.1%	+18.5%	+10%	+20%	
	2	.505	.110	.0556	3,060	55,040	- 4.5	19.2	9	20	
	3	.503	.112	.0563	3,005	53,370	- 3.9	16.5	9	20	
Base Metal Tensile Test Top	4	.505	.110	.0556	3,660	65,830	- 0.7	15.6	9	15	
	5	.506	.110	.0557	3,660	65,710	- 3.1	14.7	9	15	
	6	.505	.110	.0556	3,655	65,740	- 3.9	13.7	9	15	
Base Metal Tensile Test Bottom	7	.508	.108	.0549	3,070	55,920	*	*	12	18	*Failed @ 0.2" Gage Mark
	8	.501	.105	.0526	3,025	57,510	+ 2.5	16.7	14	19	
	9	.508	.105	.0533	3,050	57,220	+ 2.8	16.3	14	19	
Face Bend Test	10						+ 8.4%				
	11						9.6				
	12						11.6				
Root Bend Test	13							30.3%			
	14							19.9			
	15							32.1			
Cup Test Weld	16	@ 3/16"					9.5	11.6			
	17	"					13.5	15.2			
	18	"					21.1	13.6			
Cup Test Base Metal	19	@ 3/16"					9.2	4.2			
	20	"					10.3	5.8			
	21	"					8.5	4.5			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				

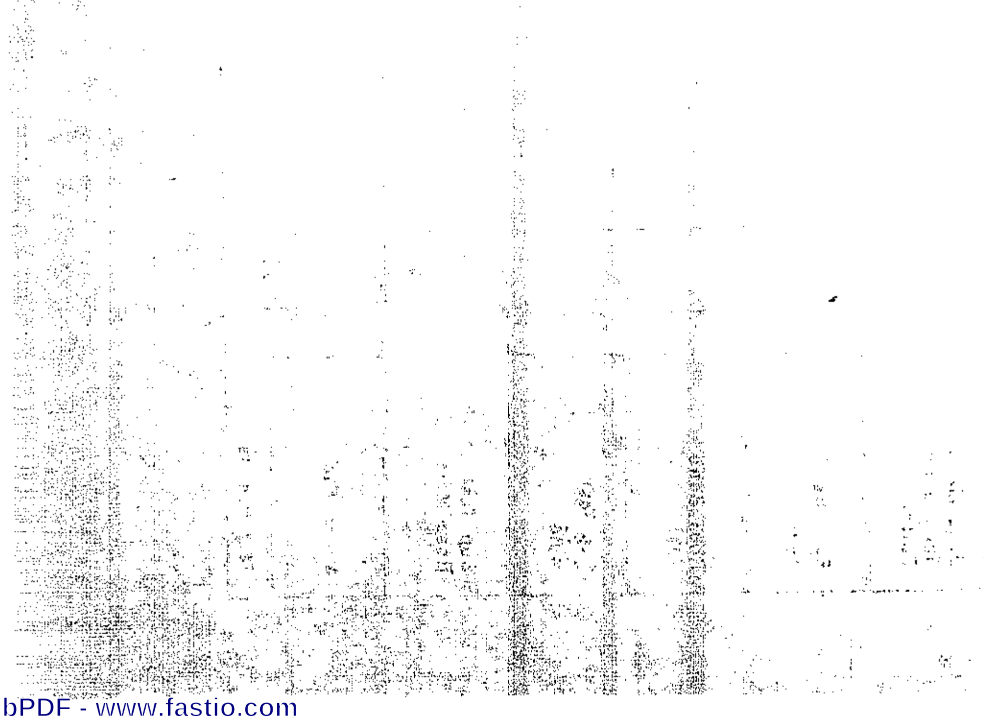
#17

Pipe Diameter = 42"　　Pipe Gage = 14　　Heat Number 471W0008

TEST TYPE	SPECIMEN NUMBER	SIZE WIDTH	SIZE THICKNESS	AREA IN^2	ULTIMATE LOAD	ULTIMATE STRESS	% ELONG. 0.2" FACE	% ELONG. 0.2" ROOT	% ELONG. 2" FACE	% ELONG. 2" ROOT	REMARKS
Across the Weld Tensile Test	1	.504	.082	.0413	2,175	52,660	- 1.1%	+13.5%	+10%	+18%	
	2	.505	.081	.0409	2,145	52,440	- 3.1	11.8	11	17	
	3	.507	.081	.0411	2,185	53,160	- 0.4	14.6	11	17	
Base Metal Tensile Test Top	4	.502	.077	.0387	2,190	56,590	*	*	14	20	*Failed @ 0.2" Gage Mark
	5	.504	.078	.0393	2,230	56,740	+ 0.7	11.1	14	20	
	6	.505	.078	.0394	2,230	56,600	+ 1.1	10.0	9	21	
Base Metal Tensile Test Bottom	7	.506	.074	.0374	2,230	59,630	+ 1.0	12.0	15	20	
	8	.501	.075	.0376	2,240	59,570	- 0.6	9.4	12	17	
	9	.505	.074	.0374	2,210	59,090	+ 0.4	12.3	14	19	
Face Bend Test	10						+ 6.1%				
	11						4.1				
	12						4.9				
Root Bend Test	13							+21.0%			
	14							19.4			
	15							21.2			
Cup Test Weld	16	@ 3/16"					+ 6.6	6.0			
	17	"					6.6	12.8			
	18	"					7.4	7.3			
Cup Test Base Metal	19	@ 3/16"					11.2	6.6			
	20	"					9.6	6.9			
	21	"					8.9	7.7			
Micro-Etch	22										O.K.
	23										O.K.
	24										O.K.
Test Results	☒ Satisfactory						☐ Unsatisfactory				







APPENDIX B

MATERIALS AND RESEARCH DEPARTMENT

State of California
Department of Public Works
Division of Highways

Test Method No. Calif. T665-~~B~~
March 15, 1969
(15 pages)

SEAM QUALITY CONTROL STANDARD FOR

HELICAL CONTINUOUSLY WELDED SEAM CORRUGATED METAL PIPE

Scope

This method describes the procedure to be followed in determining the quality of the seam of a helical continuously welded seam corrugated metal pipe. The procedure to be used involves physically distorting a short length of welded seam by using a 1 inch diameter hemispherical punch and a 1½ inch inside diameter contoured die. The resulting distorted weld area will hereafter be called the "cup".

This test method is tentative and subject to future changes as additional test data and experience with this fabrication method are acquired.

In the event of a disagreement between the fabricator and the Engineer, the referee test described in Section G shall be performed.

Procedure

A. Apparatus
   1. Die. A die having an inside diameter of 1½ inches and machined to conform to the corrugation of the sample (see Figure I).
   2. Punch. A punch consisting of a 1 inch steel ball (see Figure I).

B. Test Preparation
   1. Weld reinforcement may or may not be blended smooth on the automatically machine welded seam prior to the cup test.
   2. Weld reinforcement shall be blended smooth on manually welded seam repairs if a cup test is required (see 6 in Section D).

C. Test Procedure
   1. Position the punch on one side and centered over the welded seam at a distance of not less than 3 inches nor more than 18 inches from the end of the pipe (see Figure II). This will normally be done near the trailing end of the pipe length.

2. Center the 1 inch diameter punch opposite the die (on the other side of the welded seam). Using a suitable loading device, force the punch into the welded seam to obtain a residual cup deflection of at least 1/8 of an inch (see Figure III).
3. The direction of the cup shall be with the concavity of the corrugation (see Figure III).

D. Inspection and Evaluation
1. For a length of a pipe to be acceptable, the sum of the lengths of cracks or other defects on either side of the cup shall not be more than ¼ inch.
2. If the first cup indicates a failure, punch a second cup at another location on the weld not less than 3 inches nor more than 12 inches from the first cup (and in the direction of the center of the pipe). Evaluate the pipe again as described in D-1. If this second cup also indicates a failure, the pipe is not acceptable.
3. One cup will be the maximum required for evaluation of a standard 24 foot pipe length or less where there are no seam repairs within 16 inches of the pipe end, measured along the weld, and provided the cup passes the requirements in paragraph D-1.
4. Helical welded seam corrugated metal pipe less than the standard 24 foot length shall be required to meet the acceptance criterion of paragraphs D-1 or D-2.
5. It is the prerogative of the manufacturer to remove the defective portion of the length of pipe and retest as per paragraphs D-1 or D-2.
6. It is the prerogative of the manufacturer to manually repair defects in the automatic weld seam, provided no single defect requires a repair exceeding 16 inches in length. If, however, a repair occurs within 16 inches of either end, measured along the weld, a satisfactory test, both on the manually repaired section and also on the immediately adjacent automatically welded section, must be conducted. If either test results in failure under the criterion of paragraphs D-1 or D-2, the pipe length shall be rejected.
7. Helical welded seam corrugated metal pipe of lengths greater than 24 feet but less than 50 feet shall be required to meet the criterion of paragraphs D-1 or D-2 at each end of the pipe. If either end is rejected, the entire length shall be rejected.
8. Helical welded seam pipe of diameter greater than 48 inches shall be subject to the following additional requirements:

   When a length of pipe is rejected by the standard trailing end cup test (see paragraphs C-1, D-1 and D-2), test the following length of pipe on the leading end <u>in addition</u> to the standard trailing end cup test. If either of these two tests shows failure, reject the entire length.

9. The pipe seam shall exhibit continuous weld throughout the length of pipe with no visible indications of weld defects.
10. When a length of weld seam exhibits visible defects that would obviously fail the cup test requirements in paragraph D-1 if conducted over the defective area, the length of pipe is not acceptable. Corrective action may be taken as described in paragraph D-6.

E. Weld Corrosion
1. A welded seam with the spelter coat burned back more than 3t (three times the thickness of the pipe wall) will not be acceptable until corrective measures are taken as specified in the following paragraph.
2. Where spelter coat burn-back exceeds 3t, the weld and damaged area adjacent to the weld shall be cleaned and painted with zinc-rich paint in accordance with Section 55-3.28 of the California Standard Specifications.

F. Reporting of Results

No formal test report will be made. This test will be part of the routine quality control and plant inspection procedure for acceptance of the pipe, which is reported on Form R-29, Report of Inspection. Rejections will be reported verbally to the manufacturer.

G. Referee Test
1. The referee test consists of a destructive test requiring two 2' x 2' samples of pipe of the diameter, gage, and heat number of concern containing a 2' length of weld running through the center. The referee test may be requested by either the pipe manufacturer or the State inspector.
2. Each sample shall contain physical test specimens and micro-etched specimens of the number and type as follows:

No. Req.	Type
3	Tensile tests across the weld
3	Tensile tests of the base metal above the weld
3	Tensile tests of the base metal below the weld
3	Face bends
3	Root bends
3	Cup tests on the weld
3	Cup tests on the base metal
3	Micro-etched specimens of weld cross section

3. The specimen layout on a pipe sample is as shown in Figure IV.

4. All tensile test specimens shall have 0.200" and 2.00" gage lengths on both sides across the weld area. The data resulting from the base metal and across the weld tensile tests shall be:
   a. Ultimate load accompanied with the ultimate stress.
   b. Percent elongation of both the 0.200" and the 2.00" gage lengths on both the face and root sides.
5. All face and root bend specimens shall have a 0.200" gage length on their appropriate sides across the weld area. The data resulting from the face bend test shall be the percent elongation of the gage length after having been guided around a ½" diameter mandrel. The data resulting from the root bend test shall be the percent elongation of the gage length after having been forced flat.
6. All cup tests shall have a 0.200" gage length on both sides of the cup, across the weld area, and located and measured at the crown of the cup. The data resulting from the cup tests shall be the percent elongation evaluated on both the face and root sides of the cup at increments of 0.050 inch cup depth to 0.250 inch. The direction of the cup shall be with the concavity of the corrugations.
7. All micro-etched specimens shall be mounted and viewed for weld joint defects such as lack of fusion or cracking.
8. The test conclusions shall be made by the Engineer after having reviewed the sample test data.

Notes

Figure V shows a gage recommended for use in measuring various dimensions in connection with the cup test and also for checking acceptable width of the area burned by welding. It is used in the following manner:

1. The projections at the top of the gage do not pertain to the cup test. They are dimensioned horizontally in accordance with the widths of burned area (3 times thickness of metal) acceptable under specifications for each indicated gage of metal. The indicated widths are based on specified gage thicknesses listed in AASHO specification M36 (see Figure VI).
2. The 3" overall length dimension is used to check the following requirements of the test method:
   a. The test shall be made not less than 3 inches from the end of the pipe (see paragraph C-1 and Figure VII).
   b. The minimum distance between 2 cup tests is 3 inches (see paragraph D-2 and Figure VIII).

3. When the gage is positioned on the pipe so that the bottom legs straddle the convex side of the cup, the 0.406" wide projection should always touch the cup. The interval corresponds to the minimum allowable cup deflection (1/8"). See paragraph C-2 and Figure IX.
4. The side projections (1/4" wide) can be used to check conformance to the limiting requirement of 1/4" maximum for weld defects (see Figure X).

REFERENCES

A California Method
AASHO Designation: M-36
California Standard Specifications
End of Text on Calif. T665-B

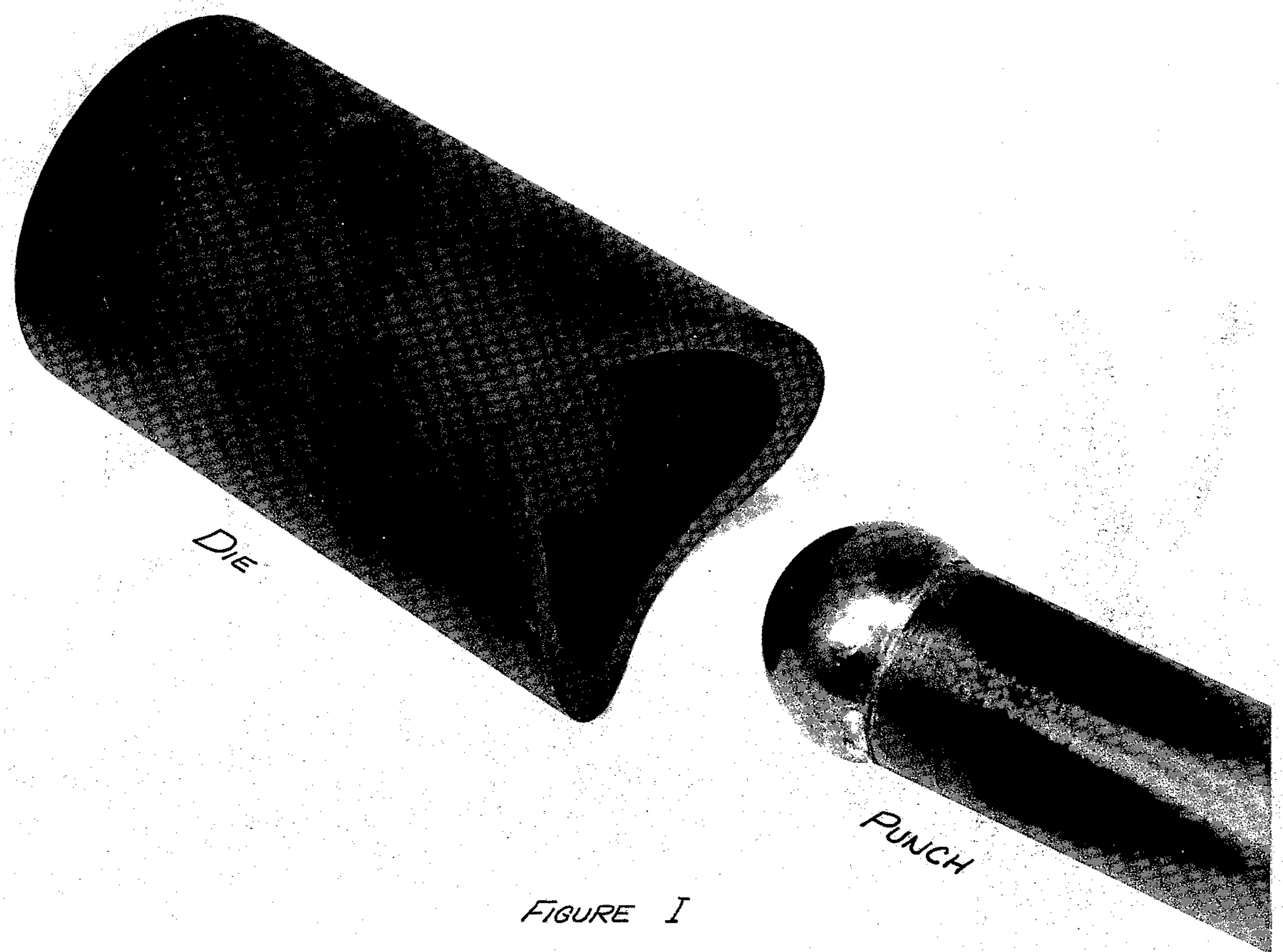


FIGURE I
DIE AND PUNCH

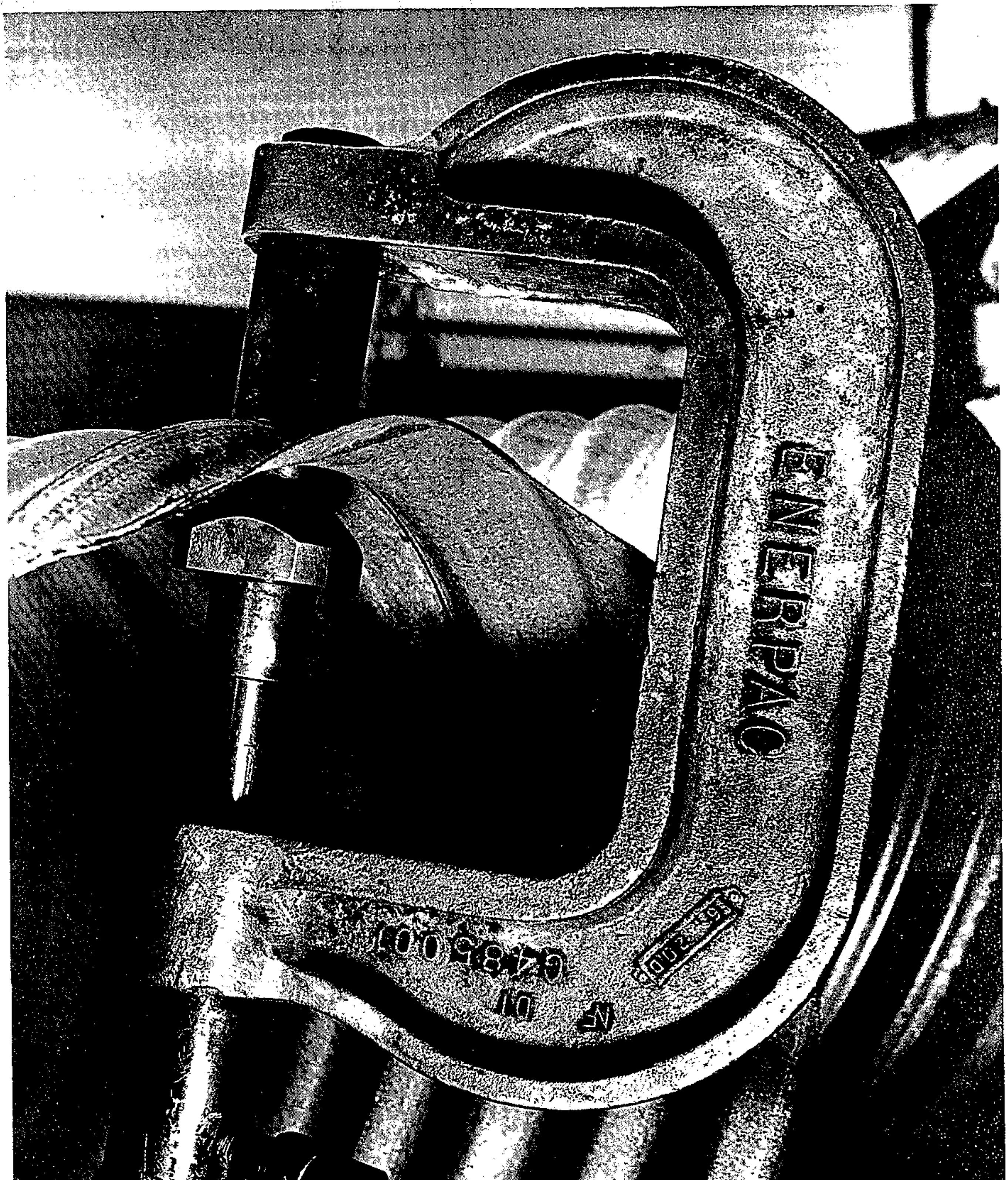


FIGURE II

POSITIONING THE DIE AND PUNCH

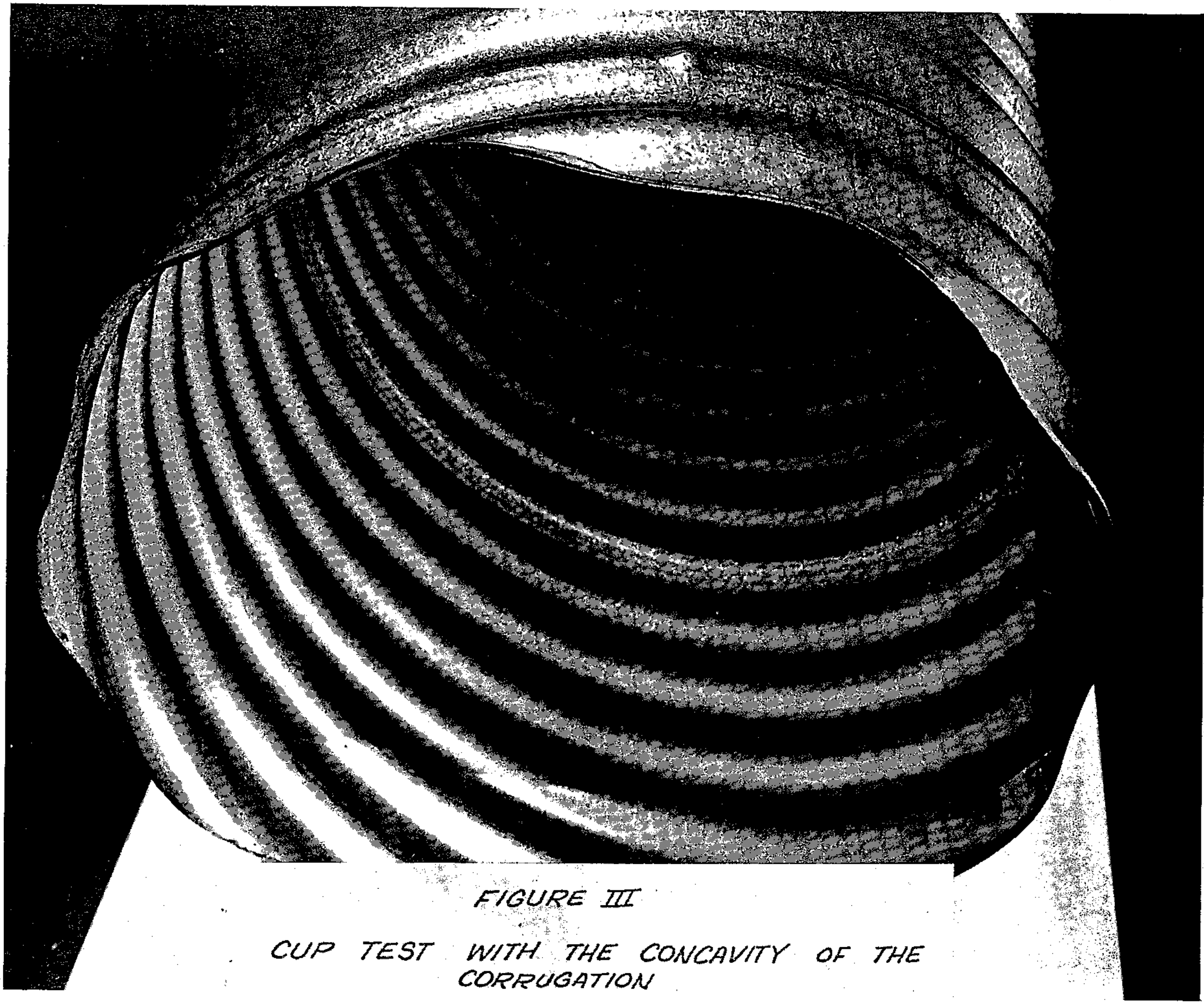


FIGURE III

CUP TEST WITH THE CONCAVITY OF THE CORRUGATION

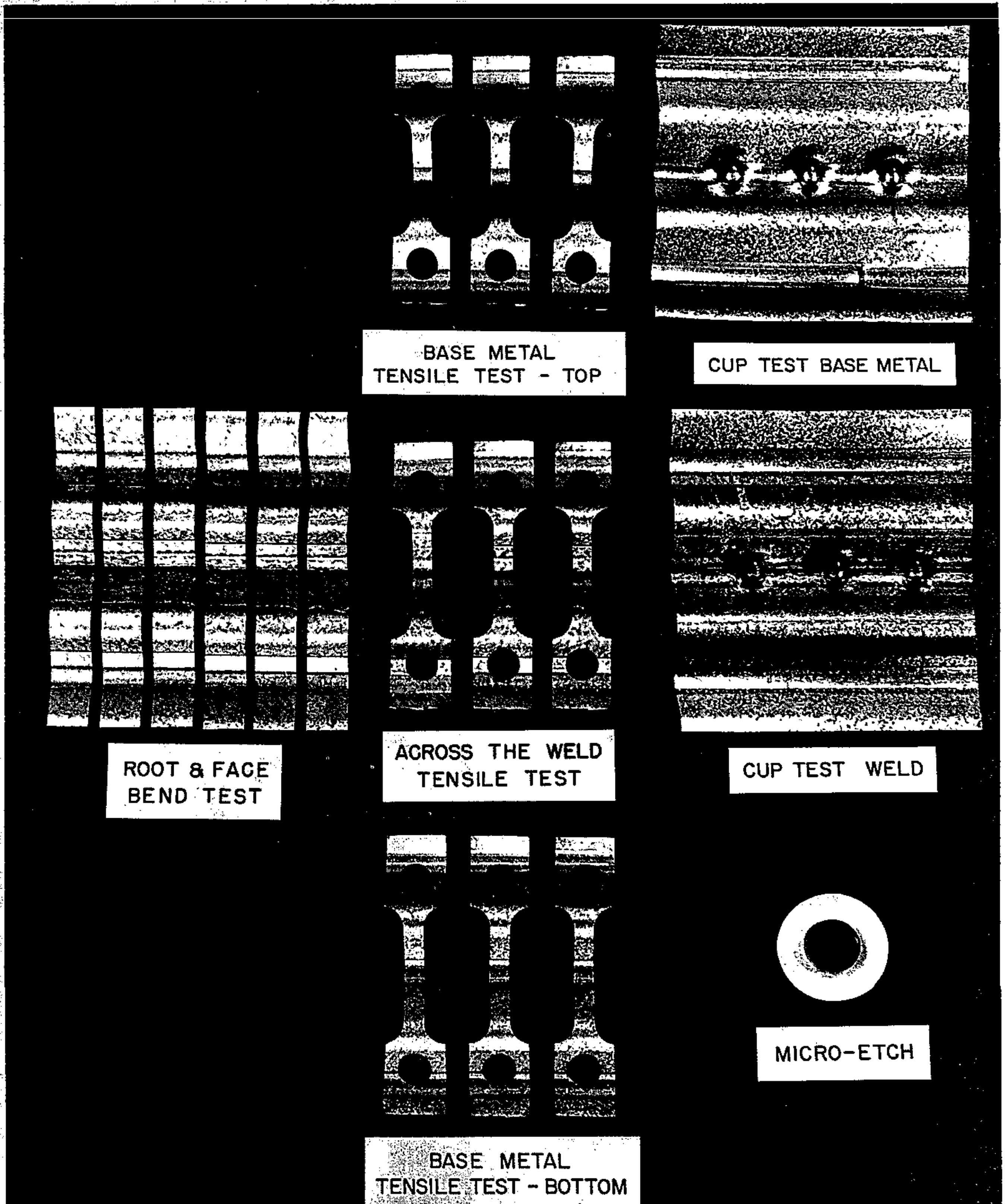
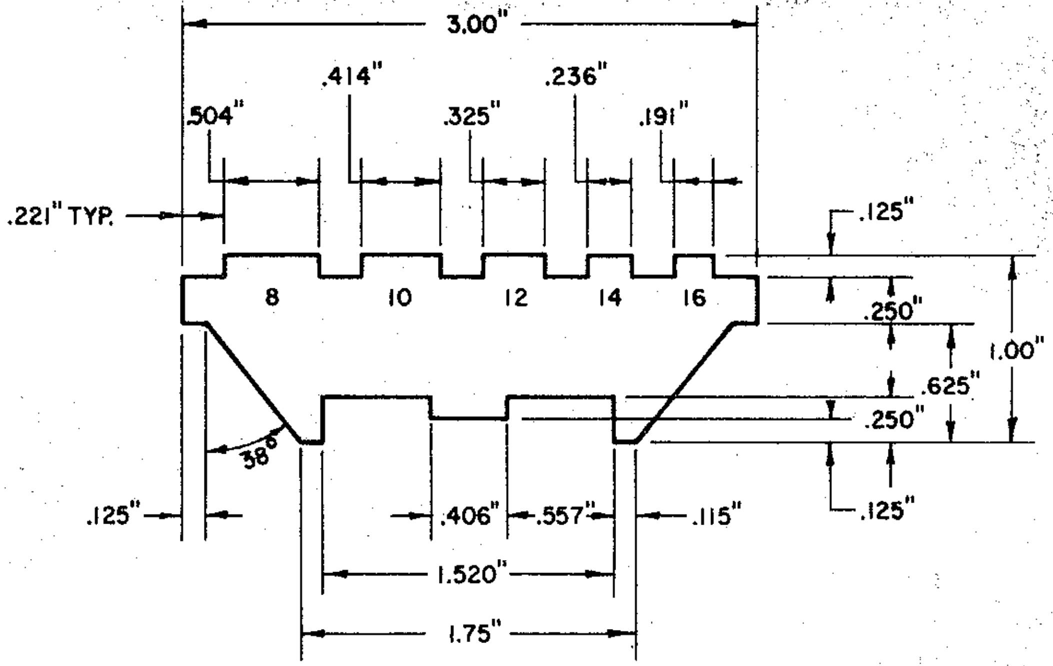


FIGURE IV

REFEREE TEST



MATERIAL – 3/32" STAINLESS STEEL

FIGURE V

CUP GAGE

FIGURE VI

MEASURING SPELTER COAT BURNED AREA

FIGURE VII

MINIMUM ACCEPTABLE DISTANCE FROM THE END OF THE PIPE TO THE FIRST CUP TEST

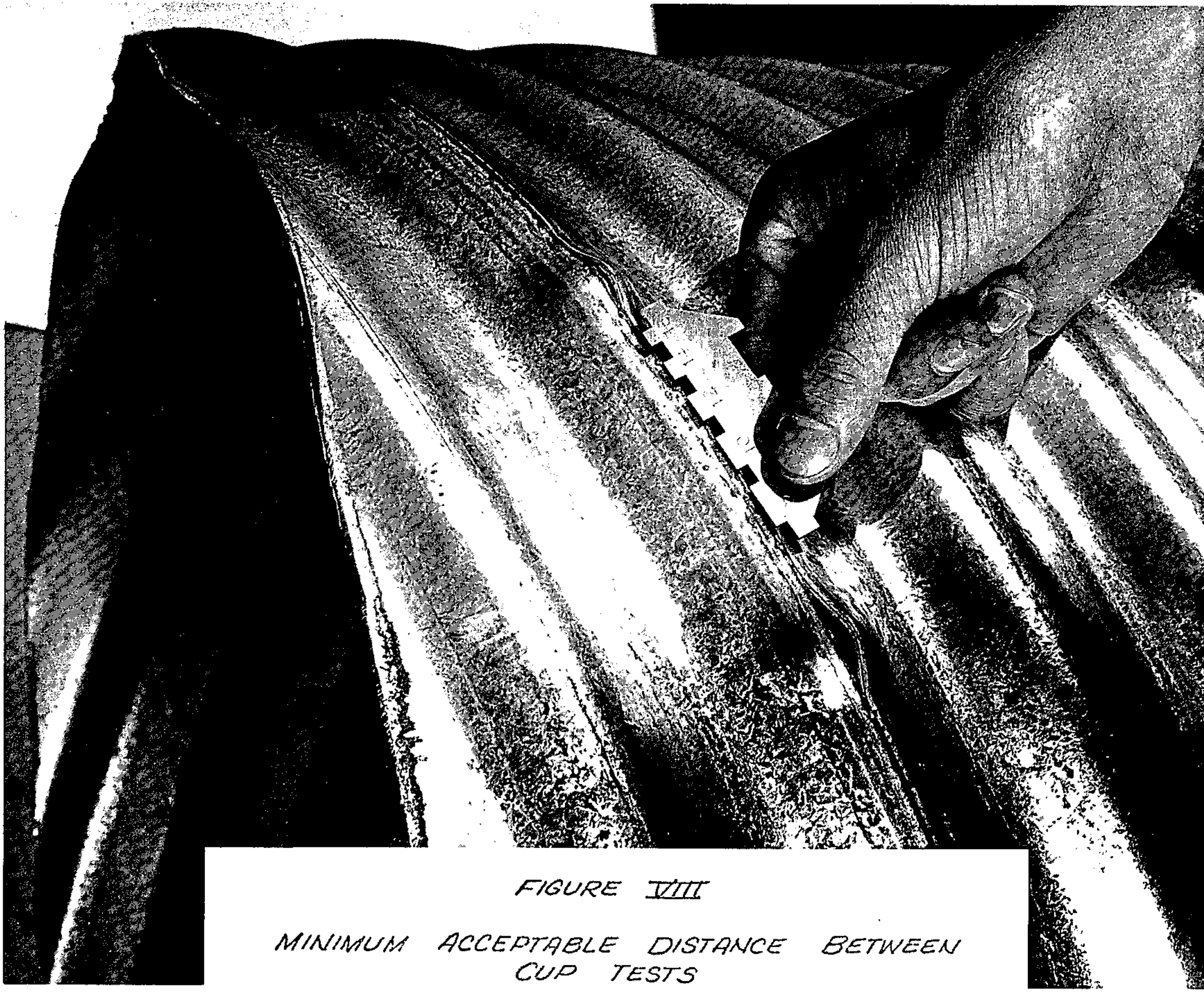


FIGURE VIII

MINIMUM ACCEPTABLE DISTANCE BETWEEN CUP TESTS

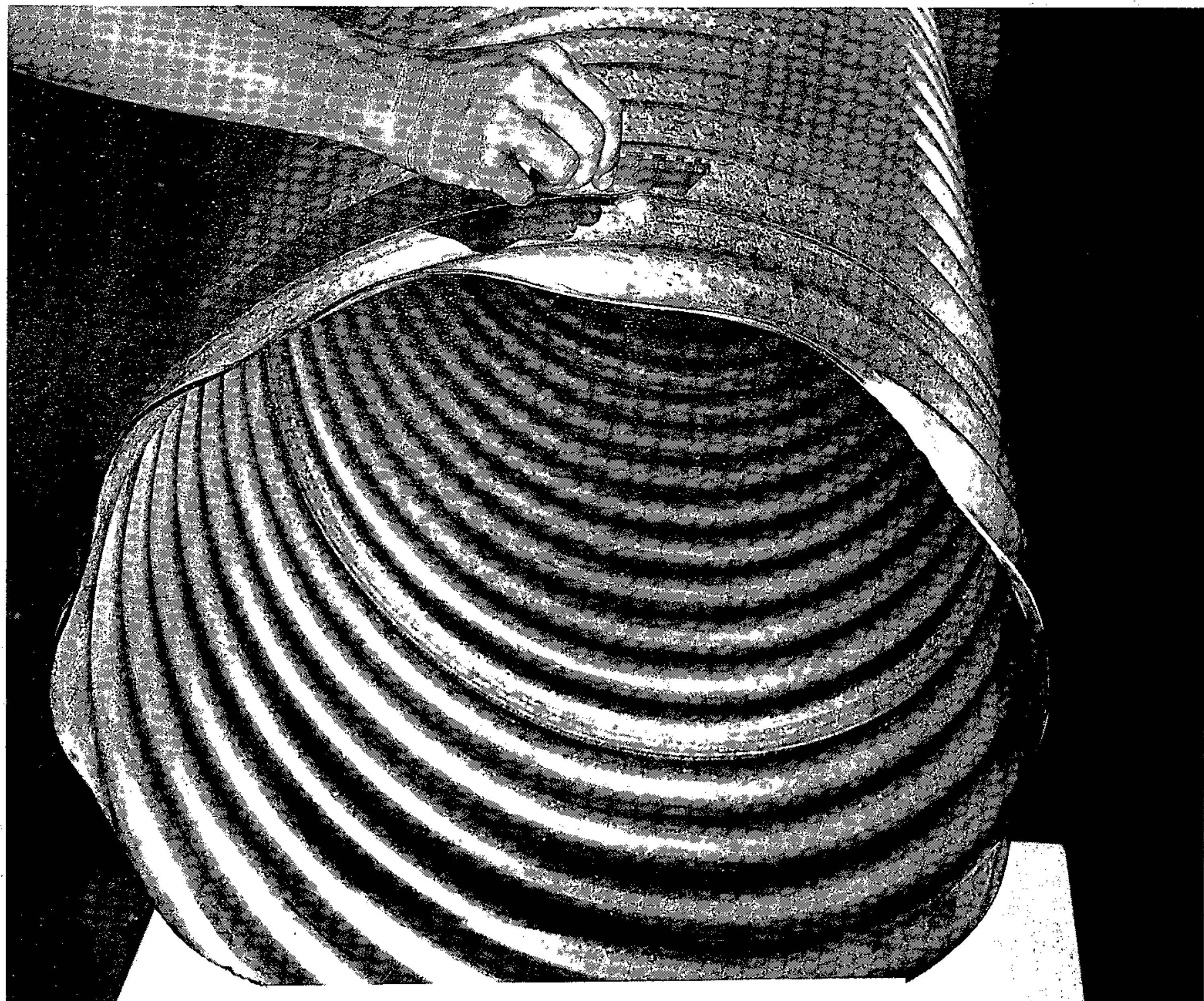


FIGURE IX

CUP DEPTH ACCEPTANCE

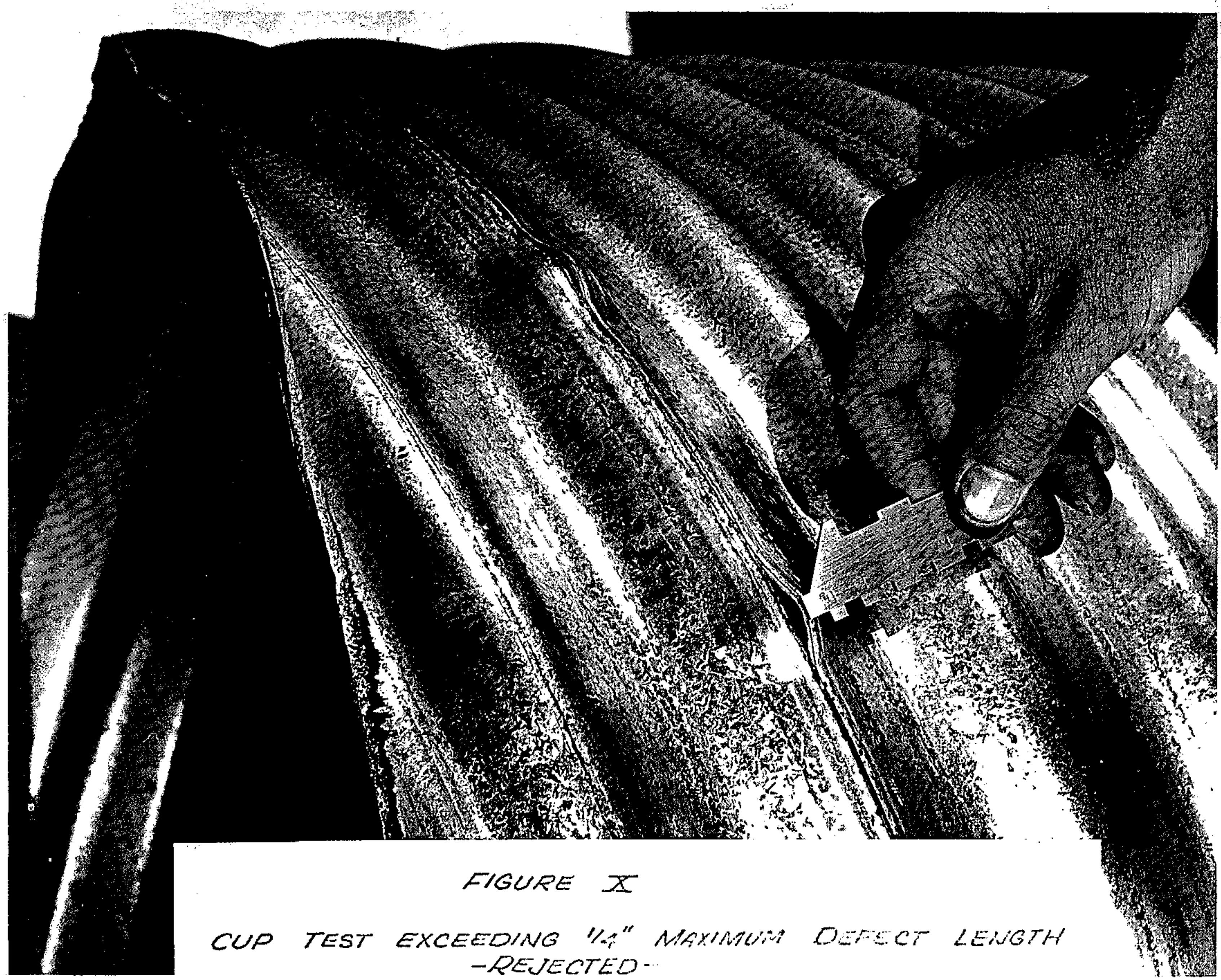


FIGURE X

CUP TEST EXCEEDING 1/4" MAXIMUM DEFECT LENGTH
-REJECTED-